

GUIDE TO ANALYSIS

IN

GEOLOGICAL AND AGRICULTURAL CHEMISTRY.

BY AN OFFICER

OF THE

BENGAL ENGINEERS.

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A GUIDE TO ANALYSIS, &c.

PART I.

OUT-DOOR EXAMINATION.

SECTION I.

1.—To the Geological reader the first obstacle generally to his applying his book knowledge to practice, is the want of any ready and practical means of testing the specimens which he meets with in his out-door rambles.

2.—I have seen much discouragement arise from informing a person who has brought home a pocket-full of pebbles, some of which at least he imagines to be good specimens, that from beginning to end they are all Quartz. It would require but little practical knowledge, joined to the aid of the point of the penknife, to have foretold this, and to have saved the tyro from the trouble of carrying his burden of Quartz pebbles. Other means as simple as the penknife will enable the observer to test primarily in the field the specimens he may encounter, and ascertain how far, and in what form or degree, they may possess some of the following qualities, which serve to distinguish minerals.

3.—1. External Form—2. Structure—3. Fracture—4. Frangibility—5. Hardness—6. Transparency—7. Lustre—8. Flexibility—9. Elasticity—10. Color—11. Double Refraction—12. Touch—13. Taste—14. Odour—15. Streak—16. Powder—17. Adhesion to Tongue—18. Magnetism—19. Electricity—20. Phosphorescence—21. Specific Gravity—22. Cleavage.

4.—The hammer and the penknife are necessary and invariable accompaniments to the out-door observer, and in addition to these may be carried without trouble a pocket lens, a small glass bottle (enclosed in a wooden one), containing a little muriatic acid, and perhaps a magnet or compass.*

* These articles may be obtained of the proper kind through Mr. Rose, No, 1, Drummond Street, Edinburgh, or from Mr. Tennant, 149, Strand.

5.—The most importa[illegible]ions mentioned, are perhaps Nos. 1, 2, 5, and 21, but the last cannot be determined in the Field, although "weight" may, and with much utility be rudely guessed by hand.

6.—The Lens is useful to determine Nos. 1 and 2; the penknife for No. 5. The acid for testing limestones or the presence of Carbonic acid, and without the Hammer specimens could neither be interiorly examined, as to Nos. 2, 3, and 4, nor indeed could they, in a majority of cases, be obtained at all, in a convenient form and size.

7.—Such being the portable implements to be made use of then, the observer must direct his attention as regards the before-mentioned qualities, to the following points:—

1st. EXTERNAL FORM.

8.—This is either *crystallized* or *massive.* The number and variety of crystals is endless, and books on Mineralogy must be consulted to comprehend the niceties of their formation, but for general purposes it may suffice to note as follows:—A crystal is a regular geometrical solid, and consists of planes, edges, solid angles. An edge is formed by the meeting of two planes; a solid angle by the meeting of three or more planes; truncation is the removal of tops, edges, &c.; replacement of an edge is the substitution for it of one plane, bevilment is the substitution of two planes.

9.—Crystals are arranged into six classes or systems, the distinctive characteristics of which are the length and relative position of their axes, which are lines joining either the opposite angles or the centres of opposite faces.

The first is the regular system: it has all its axes equal and at right angles to each other. The Octahedron or two four sided pyramids placed base to base is the simplest form of it. The Cube is a modification, and Alum, Iron-Pyrites, Fluor Spar, Galena, Garnet, Sal Ammoniac, Native Iron, Platinum, Copper, Silver, Gold and Bismuth, the Diamond and Rock Salt are instances of it.

The second is the square prismatic system: two of the axes are equal; the third is either longer or shorter, and all are at right angles to each other as before. Tin Ore is an instance, also Copper Pyrites in a modified or Tetrahedral form.

The third is the hexagonal system. It has four axes, three of which are equal and at angles of 60° with each other. The fourth is of unequal length, but at right angles with them. Quartz, Emerald, Sapphire,

Apatite, Graphite, Red Oxide of Zinc, Chlorite are instances, and in the modified forms numerous other minerals, as Calc Spar, (rhombohedral,) Corundum, Specular Iron, Tourmaline, Manganese Spar, Native Antimony and Arsenic, Calamine (Carbonate of Zinc,) Cinnabar, (Sulphuret of Mercury,) Nitrate of Soda.

The fourth system is the Rhombic. It has, like the first and second systems, three axes at right angles to each other, but no two are equal. Saltpetre, Sulphur, Heavy Spar, (Sulphate of Barytes,) Sulphuret of Antimony, Olivine, Pyrolusite, (Peroxide of Manganese,) Epsom Salt, Chrysoberyl, Talc and Topaz, are instances.

The fifth is the Monoclinic or oblique Prismatic system. It has, like the last, three unequal axes, and in addition it has a push to one side as it were; one of the axes being at right angles to the other two, but these latter are not at right angles with each other. Felspar, Hornblende, Actinolite, and Amphibole (forms of Hornblende,) Gypsum, Hypersteme (a form of Augite.) Wolfram (Tungstate of Iron) Heulandite, Azurite, Mica, Malachite, are instances.

The sixth is the Triclinic or doubly oblique Prismatic system. This has a double lurch. The three axes are unequal and also no one is at right angles to the other two. Instances of this are rare. Albite, Blue Vitriol, Manganese Spar, and Labradorite are among them.*

10.—Massive or Amorphous appearance is distinguished, as its name imports, from Crystalline by having no regular form.

2ND.—STRUCTURE.

11.—May be *Foliated* or *Massive, Fibrous, Columnar,* &c.

Foliated, Laminar or *Slaty,* as Talc and Mica.

Massive.—This may be either

Granular, as		*Compact,* as
Sandstone Limestone Chalk,	or	Felspar and Gypsum.

Fibrous which may be

Parallel	Divergent	Radiated
as Gypsum.	as Mesotype.	as Wavellite.

Columnar (species of Fibrous) as Basalt.

* By Dana, these 6 classes are arranged in the following order—1, 2, 4, 5, 6, 3, and are called from the characteristics already given—1. The Monometric—2. The Dimetric—3. The Trimetric—4, The Monoclinate—5. The Triclinate—6. The Hexagonal. And this arrangement is perhaps easier to fix in the memory.

12.—With reference to the aggregation of their particles, minerals may be conveniently described as

Brittle. If the particles lose their coherence and separate with a grating noise into powder, when we attempt to alter their respective situations in the substance. As the Gems, Spars, Pyrites, and many other minerals.

Malleable. When the particles being detached by knife, do not lose their connection; so that from such a mineral we may detach slices, as from metallic lead.

Sectile. When (as Mica) they cannot be sliced, and when cut, lose their mutual connection, but instead of flying about, remain quietly upon the instrument.

Flexible. If the particles admit of their relative situations being changed, and do not resume their former position; and lastly

Elastic. If having been so changed, they resume their former situation when the force is removed.

3RD.—FRACTURE.

13.—May be *Even, Uneven, Conchoidal* or *Splintery.*

It is *Even* when the fragments split off regularly, as in Jasper.

Uneven—When the fragments are irregular, as Rose Quartz, Cinnamon Stone.

Conchoidal—When the fracture is like a shell, concave and circularly marked, as in Obsidian and Flint.

Splintery—As in the Flint with sharp edges.

4TH.—FRANGIBILITY.

14.—May be *Easy* and *Difficult*; *Easy,* as in Obsidian and Pitchstone; *Difficult,* as in Rock Cork.

5TH.—HARDNESS.

15.—Minerals are generally referred as regards their hardness to a scale, as below, commencing at the softest.

1. Talc—2. Selenite (semi-crystallized Sulp. of Lime or Alabaster) or Rock Salt—3. Calcareous Spar or Calcite—4. Fluor Spar—5. Apatite (Phosphate of Lime)—6. Felspar—7. Quartz—8. Topaz—9. Corundum—10. Diamond.

The relative hardness of a mineral may be ascertained by attempting to scratch it with, or to scratch with it, some of the minerals of the above scale. Its actual hardness is usually tried with a penknife, after

using which on any convenient exposed surface, it is well to pass the finger over it, in order to clear it and ascertain whether a true scratch, and to what amount, has been made.

6TH.—TRANSPARENCY.

16.—This is considered—

Transparent—When objects can be distinctly seen through the specimen, as Rock Crystal, Crystallized Carbonate of Lime.

Semi-transparent—When objects are indistinctly seen, as Milk Quartz.

Translucent—When light can be seen, but not objects, as Chalcedony, Crysoprase.

Opaque—When they fail to transmit light, as Jasper and all minerals.

17.—Transparency is a very doubtful test, as minerals themselves vary according to the coloring matter they may be incorporated with; and their own varying degree of thickness gives also varieties of transparency.

7TH. –LUSTRE.

18.—Is *Internal* as well as *External*, and is divided into—

Metallic. Such as the metals, Pyrites, Copper, and Iron Crystals. Anthracite has generally imperfect but occasionally perfect metallic lustre.

Adamantine.—As the Diamond, Carbonate of Lead.

Pearly.—As Talc, native Magnesia, Gypsum. This frequently accompanies incipient decomposition.

Silky.—As fibrous Gypsum.

Resinous.—That of Rosin, Opal, Zinc blende. It is a slightly oily look.

Vitreous.—As Quartz, Emerald.

Glistening (as opposed to *Dull* or *Earthy*).—The former, when a mineral is made up of many shining particles, like Statuary Marble. Talc also, and Copper Pyrites. The latter as Chalk.

8TH.—FLEXIBILITY.

19.—*Talc* is flexible and not elastic. Mica is elastic and flexible.

9TH.—ELASTICITY.

20.—Mentioned above with flexibility.

10TH.—COLOR.

21.—Is of all varieties.

11TH.—DOUBLE REFRACTION.

22.—Transparent Carbonate of Lime is transparent and doubly refracting, representing two images of the object seen through it, while Rock Crystal is not, nor is Sulphate of Lime.

12TH.—TOUCH.

23.—*Rough*, as Trachyte (volcanic Felspar) Aluminite.

Smooth—As Mica.

Unctuous—Talc, Steatite and Serpentine slightly.

Meagre.—When the surface seems to rub off in powder under the finger as Chalk.

13TH.—TASTE.

24.—This is applied to deliquescent minerals, as Rock Salt, Sulphate of Magnesia or Epsom Salts, &c. It may be *astringent*, as Vitriol; *sweetish-astringent*, as Alum; *alkaline*, as Soda; *saline*, as Salt; *cooling*, as Saltpetre; *bitter*, as Epsom Salts.

14TH.—ODOUR.

25.—This is apparent in some Limestones, containing Hydrogen as well as Carbonic Acid, which when rubbed smell strongly of Gas, or Carburetted Hydrogen—also some varieties of Quartz.

Some also, as the clays, have an earthy smell when breathed on.

Others when struck with the hammer; as ores of Cobalt and Arsenic which then smell of garlic. Those of Selenium, when heated have the smell of horse radish, and Sulphurets that of Sulphur.

15TH.—STREAK,

26.—Or the color of the scratch made on a mineral with the penknife, file, &c., which in some cases is of the color of the mineral, as a *black* streak on black Tourmaline; sometimes *white* on a black mineral, as on Hornblende; sometimes *shining*, as in Plumbago, *bright*, as in Iron ores; *dull*, as in Clay Stones.

27.—This character may be examined either by scratching the mineral with a point as that of a penknife harder than itself, or, when not too hard, by rubbing it upon a piece of unglazed Porcelain. The application

of the point may produce a rough or a smooth line, and with or without powder.

Where powder is produced, it may be either *white* or *colored*, and, if *colored*, it may be of the same tint as the mineral or different from it. The lustre of the smooth line is sometimes greater than that of the mineral.

16TH.—POWDER.

28.—The streak, as above stated, is distinguished as *shining* or *dull*. The powder is *white* or *grey-colored;* the same as the mineral, or different from it.

In rubbing say Iron ores on a harder mineral, specimens of a very dissimilar appearance may make the same colored mark or nearly so, as specular Iron ore, which, when rubbed on Sandstone (composed of Quartz and therefore harder) gives a reddish-brown mark, and oxidulated Iron a blackish-red mark.

17TH.—ADHESION TO TONGUE.

29.—Which as in some Clay Slates is considerable, from their rapid absorption of moisture.

18TH AND 19TH.—MAGNETISM AND ELECTRICITY.

30.—Some of the Iron ores are magnetic, and also generally the crystalline Trap Rocks, as distinguished from the fragmentary Grey wackés. This quality is variable in degree; for instance specular Iron ore containing 69 per cent. of Iron, is but slightly magnetic. Oxidulated Iron with 72 per cent. is more so.

31.—Substances are magnetic or diamagnetic, as they attract or repel either pole of a magnet. The following enumeration of minerals is given by Phillips, in their order of power over the magnet.

Magnetic.—Iron, Nickel, Cobalt, Manganese, Chromium, Platinum.

Diamagnetic.—Bismuth, Phosphorus, Antimony, Zinc, Tin, Cadmium, Sodium, Mercury, Lead, Silver, Copper, Gold, Arsenic.

32.—As regards electricity, the Topaz and foliated Carbonate of Lime are (particularly when rubbed or in dry weather) highly electric, like Amber, and show it by attracting small pieces of paper. So also are Fluor Spar, Arragonite, Carbonate of Lead and Quartz. Heat or change of temperature excites Electricity in the following minerals—Tourmaline, Calamine, Beryl, Fluor Spar, Diamond, Garnet, &c. In Calcite the same quality may be produced by pressure.

20TH.—PHOSPHORESCENCE.

33.—Many varieties of Dolomite (Magnesian Limestone) and Calcite frequently emit light when struck with a hammer. Two pieces of Quartz phosphoresce, as may be seen in the dark when rubbed against each other either in air or under water.

Gypsum, Fluor, Calcite, Aragonite, Amber and especially some varieties of Diamond become luminous in the dark after exposure to sun light.

21ST.—SPECIFIC GRAVITY.

34.—This is taken by weighing the mineral first in air and then (attaching it by a thread to the scales) in a tumbler of water. Divide the weight in air by the difference of the two weights taken. The result will be the specific gravity.

Thus—*Topaz*,	Weight in Air,	359·5
	Ditto in Water,	258·0
	Difference,	101·5
$\frac{359·5}{101·5} = 3·54$	Its specific Gravity.	
Again Quartz,	Weight in Air,	343·5
	Ditto in Water,	211·6
	Difference,	131·9
$\frac{343·5}{131·9} = 2·6$	Its specific Gravity.	

and thus these two may be distinguished when otherwise in appearance they might not.

35.—If the substance be in the form of fine sand or very small lumps, it is better, after weighing it carefully, to take a small dry phial furnished with a stopper; counterpoise this phial accurately in the weight scale, by shot or strips of lead, then fill it completely with pure water, taking care that no bubbles of air are left in, and weigh the quantity of water it contains, afterwards empty the bottle and dry it inside.

Next fill the bottle about $\frac{2}{3}$rds full of the powder to be examined, weigh this and record the weight. Then fill the bottle once more with water taking care as before that all bubbles are expelled and none of the powder washed out. Once more weigh it.

We have then to make the following calculation:

Weight of powder and water in grains=
Deduct weight of powder alone=

Difference (weight of water in bottle)=

Weight of bottle full of water in grains =
Weight of water left in bottle when with the mineral =

Difference (weight of water displaced by and equal in bulk to powder, =

S. Gravity $= \frac{\textit{weight of powder in air.}}{\textit{weight of water displaced.}}$

22ND.—CLEAVAGE.

36.—When a mineral is broken by a hammer or otherwise split, the fresh surfaces are either flat or uneven in very different degrees. The flat surfaces are referred to *Cleavage*, and the uneven ones to *Fracture*, that is all regular fracture is *Cleavage*. Other faces parallel to the flat surfaces thus exposed may generally be discovered by splitting, or as it is termed cleaving, the mineral in the corresponding directions.

37.—Cleavages are reckoned in number by the number of parallel planes in a Crystal. Thus a cube has three cleavages, and a hexagon four, when the terminal planes or extremities are flat and parallel.

38.—Of the before-mentioned distinctive qualities of minerals, it will be seen that the eye, aided, if necessary, by the lens, may judge of Nos. 1, 6, 7, 10, 11, 16 and 20, that is the External Form, Transparency, Lustre, Color, Refracting Power, Powder (on rubbing it on a harder rock) and Phosphorescence.

39.—If the Hammer be brought into play, we may then judge of Nos. 2, 3, 4 and 22, that is of its Structure, Fracture, Frangibility and Cleavage.

40.—Taking it in the hand will test Nos. 8, 9, 12 and 19, or its Flexibility, Elasticity, Greasiness of Touch, or otherwise, and Electricity (by rubbing) as well also as weight, till Specific Gravity be ascertained.

41.—The senses of taste and smell will prove Nos. 13, 14 and 17, that is its Taste, Odour and Adhesion to Tongue.

42.—The Penknife will resolve Nos. 5 and 15, or the Hardness and Streak, as well as aid in determining others, such as Nos. 8, 9, 16 and 22.

43.—A Compass will determine No. 18; Magnetism, and the Specific Gravity can be ascertained on reaching home.

44.—In addition to these, the observer has his bottle of acid, by which he can at once ascertain if the specimen be a Limestone or contain Carbonic Acid.

45.—By the aid of these common helps, which can be so readily carried without inconvenience, it will be hard if the observer cannot arrive at some approximate idea of the nature of the specimens he encounters, supported, as he should be, by some theoretical knowledge derived from books.

NOTE.—I have not mentioned Crystalline character more at length than is done under the head of External Form, because although of the utmost importance, yet to describe the numerous modifications of the regular forms of the various systems, is a matter of such difficulty as to render it necessary to exclude it from a simple treatise like the present, and refer the reader, who desires further information, to books on the subject, such as Ansted, Phillips, Dana, &c.

SECTION II.

1.—Some of the distinguishing characteristics of the most commonly occurring Minerals may be given as follows. I must premise by saying, however, that the best possible plan for the student to follow, who wishes to become acquainted with the actual appearance of Stones and Minerals, is to obtain from those who prepare Geological Cabinets in London or Edinburgh, a small case, containing specimens of the different Stones which it is most requisite to know. Such boxes cost only 50 Rupees, and are compact and portable.

2.—*Quartz* has a vitreous lustre, resists the penknife, strikes fire with flint; has no regular cleavage; and a shelly fracture, scratches glass and most other substances, except a few gems. Crystallizes in six-sided prisms terminated by six-sided pyramids, and is infusible before the blowpipe.

3.—*Felspar*, yields with difficulty to the knife; has a peculiar lustre; does not strike fire with flint; does not effervesce with Sulphuric Acid, and is particularly characterized by its capability of being split in two directions at right angles; it becomes glassy white before the blowpipe, and fuses at the edge with difficulty. Crystalline form monoclinate.

4.—*Mica*, is separable in one direction only, has a silvery or gold color generally, and a metallic lustre. Its laminæ are elastic.

These three constitute *Granite;* and when in a finely granular or slaty and stratified state, *Gneiss.*

5.—*Mica Slate* is a compact and slaty compound of Mica and Quartz. Garnets (usually crystallizing in dodecahedrons) are often found in Mica Slate.

6.—*Clay Slate* consists of very fine particles of Mica, Quartz, Felspar, and Alumina, and is particularly characterized by its clayey odour when breathed upon or moistened with water. The Clays generally are greasy and soft to the touch, and when dry absorb moisture rapidly, in consequence of which they adhere slightly to the tongue.

7.—*Talc* is composed of Silica and Magnesia, and, like most Magnesian compounds, is soft and greasy to the touch. When solid, it forms *Steatite* or Soap-stone. It is *not* elastic, and has a pearly lustre.

8.—*Hornblende* (or Amphibole) is a blackish green Mineral, and splits in two directions at an angle of 124°. It sometimes enters into the com-

position of Granite, forming, when the Mica is absent, Syenite. It scratches with the knife, but with some difficulty. It can be distinguished from black Mica by its want of glitter, and by its laminæ separating less easily and being more brittle, and from black Augite (which however is not found in Granite) by its sharper lateral angles (124° and 56 instead of 90°) under the lens.

Hypersthene, a species of Hornblende, is known by its brownish color and semi-metallic lustre.

9.—*Syenite* is chiefly composed of Felspar and Hornblende (also Labradorite), and when the particles are very finely divided, they form

10.—*Greenstone*, or Diorite, appearing crystalline.

11.—*Hornblende Rock and Slate* are almost entirely Hornblende with a little Iron, somewhat harder than Mica slate, and occasionally more or less fibrous.

12.—*Porphyry* includes many rocks, having generally the appearance of a solid general mass, with crystals embedded in it. As, for instance, Felspar and Labradorite, with Quartz in crystals or shapeless as Hornstone. Red Porphyry has a red mass, with perhaps white Felspar crystals in it.

Chert and *Hornstone* are Chalcedony (or Quartz) in a granular state, and Chalcedony has usually the fibrous appearance of the white part of the Cocoanut. Crysoprase is apple green Chalcedony.

13.—*Serpentine* is a close grained stone, slightly greasy to the touch, composed of Silica, Magnesia, Protoxide of Iron and Water chemically combined. It is soft, scratches white, and can be turned in the lathe, and is often marked with streaks and spots. The color dark, and no stratification.

14.—*Chlorite* is Silica, Magnesia and Alumina, and being colored green by Protoxide of Iron, it resembles a very finely laminated green Mica Slate; It may be detected by its clayey smell when breathed on.

15.—*Calc Spar*, or crystallized Limestone, is in six-sided prisms like Quartz, and is easily scratched with the knife. It effervesces with acids. Common Limestones are of all colors and forms. Transparent carbonate of Lime crystals, are highly doubly refracting.

16.—*Gypsum*, or Sulphate of Lime, when crystallized in *Selenite*, splits like Mica in one direction. As *Anhydrite*, that is without the chemically combined water of Gypsum, it is generally found with Rock Salt, and splitting in three directions into Cubes is called, "*dicespar.*" As *Alabaster* it yields easily to the nail even, and it does not effervesce with acids.

17.—*Dolomite*, or Magnesian Limestone, is generally of a yellowish color; it effervesces only slightly, or when powdered, but burns to Lime like common limestones.

18.—*Fluor Spar*, or Fluate of Lime, is harder than Calc Spar, but scratches with the knife. It is found or splits in four directions into cubes, is transparent, and usually bright colored.

19.—*Clay* as met with superficially or in alluvial soil, is a chemical compound of Silica and Alumina. Some forms of it are plastic, others, as *Fuller's Earth*, are not.

20.—*Marl* may be regarded as an impure Lime, or an hydraulic Limestone of earthy formation.

21.—*Loam* (or Brick-clay) as an impure clay, containing sand and a little carbonate of Lime.

22.—*Sandstones* consist essentially of coarser or finer granules of Quartz, Felspar and Mica, with little fragments of Granite, Clay-Slate, &c., these Granules and sandy portions being connected together by a quartzose, or aluminous, or sometimes calcareous cementing substance.

When the particles are large, it becomes *Breccia* or *Conglomerate.*

23.—*Graywacké* is usually a coarse mixture of Quartz, Silicious schist, Clay Slate, &c. This class of Rocks presents a fragmentary character, as distinguished from the Trap Rocks, Greenstone, &c., which are crystalline. The latter also affect the Magnet which the former do not, and they are not stratified ever, as the Graywacké Rocks are.

The hard *Sandstones* form good material for building, for millstones, &c. The finer textured ones for Hones and Whetstones. They are often called *Freestones*, from the facility of hewing them freely in any direction.

Coal can be generally well distinguished, but to know Lignite from it is sometimes not easy. By pulverizing and boiling in solution of potash and then filtering, the Coal will present a yellow, the Lignite a brown colored liquid.

24.—*Anthracite* has a metallic aspect and Iron-black color.

25.—*Bitumen* mostly springs forth with Water from crevices in Limestone, Marls or Sandstones.

26.—*Graphite* has a metallic and Iron or Steel-grey color. It is rather soft and unctuous, and ordinarily forms finely scaled masses in Granite, Gneiss, Primitive Limestone, &c.

27.—*Rock Salt* crystallizes in cubes, and is easily told, like *Alum*, by its taste. The latter however crystallizes in octahedrons. Rock Salt is easily fusible.

28.—*Trachyte*, from the Greek *trachus*, rough, a Volcanic Stone like Basalt and Lava, is a mixture of Crystals of glassy Felspar, Quartz, Mica and Hornblende, embedded in a more or less porous matrix of Felspar with aluminous particles. The color is usually yellowish, greyish or reddish, and it looks as if disintegrated and eaten away.

29.—*Obsidian* looks like black Glass, with a conchoidal fracture, and *Pumice* is a sort of frothy obsidian.

30.—*Basalt* is a tolerably homogeneous Stone, of grey or black color, but consists really of a very fine mixture, principally composed of Augite and Labradorite (the latter to be distinguished from the Felspar which resembles it by being attacked and decomposed by concentrated Sulphuric Acid.)

This mixture is often perceptible in *Dolerite* and *Augitic Porphyry*, and in *Amygdaloid*, so called from its almond-shaped cavities.

Trachyte and Basalt are good building Stones, but hard to work, the former is much used in the Cathedral of Cologne.

31.—*Augite*, from the Greek *auge*, lustre, is a siliceous compound of Lime, Magnesia and protoxide of Iron, and is frequently met with in prismatic Crystals, cleavable very nearly at right angles, which fact serves to distinguish it from the sharper angles of Hornblende. It gives (with magnetic Iron ore) the black color to Basalt.

32.—The *Metallic Ores* generally are known by their weight, for they frequently do not present the aspect indicative of an ore. *Meteoric Iron* has a thin crust of Nickel, but it rarely exhibits its crystalline structure till a polished surface is acted on by acid, which brings to light triangular and other regular figures.

33.—*Magnetic Iron Ore* is in octahedral Crystals and compact granular masses of an Iron-black color, and black powder, when scratched or rubbed on hard Sandstone, and magnetic.

34.—*Hematite*, or *Red Iron Ore*, has a reddish-black aspect, but the color of the powder is red, cherry red, or brownish red.

35.—With the exception of some of the varieties of red Hematite, the Iron Ores do not act upon the magnetic needle, but the effect becomes evident after they have been sufficiently heated on charcoal before the blowpipe.

36.—*Brown Hematite* has an orange yellowish streak.

37.—*Carbonate* of *Iron* occurs in small Rhombic Crystals of pearly lustre; streak generally white. It might be distinguished from Limestone, by being heavier and by becoming magnetic under the blowpipe, while the other would turn white; from Sandstone, by its surface being

smoother generally; and from Quartz, by its being not so hard and heavier.

38.—*Clay Ironstone*, an impure Carbonate, is generally of greyish black color inside and outside; streak greyish white.

39.—*Blackband Ironstone*, the same, with dark carbonaceous matter.

40.—*Iron Pyrites* in octahedral or cubical Crystals, yellowish color and very hard, nearly as hard as Quartz. It is never used for its Iron, but for its Sulphur and green Copperas, or Sulphate of Iron. Not magnetic.

41.—*Copper* rarely occurs pure in distinct Crystals (cubes or octahedra,) but usually in compact masses, laminated incrustations and dendridic or arborescent. It can be told by its color, and yielding when cut at once to the knife.

42.—*Burnt or Purple Copper Ore* is found in India.

43.—*Copper Pyrites* is yellowish and of acute Rhombic form.

44.—*The Red Oxide* is Ruby-red, soft, massive and crystallized in the octahedron form.

45.—*Malachite and Azurite* known by their green and blue colors.

46.—*Zinc* does not occur pure in nature, and its ores have so little of a metallic aspect, that they are not easily known.

47.—*Silicious Oxide* of *Zinc* and *Calamine or Carbonate of Zinc* occur in crystalline rods and granules, and in earthy masses of white, yellowish or greenish color. The latter effervesces slowly with Acid, and is usually found of an earthy nature, and pearly lustre. Its primary crystalline form is the hexagonal.

48.—*Zinc Blende*, or Sulphuret of Zinc, is of a higher and splendent lustre, brittle, and splits with ease; softer than Tin, which is impervious to the knife, and known from Lead by its color being brownish instead of bluish, and its powder dark-brown instead of black. Its crystals are Octahedral.

49.— *Sulphuret of Lead*, or Galena, occurs in cubical crystals, and frequently in granular masses, color is lead grey—lustre metallic. Very brittle and very heavy. When massive it is foliated. It yields readily to the knife, and its powder is blackish.

50.— *Carbonate of Lead* has a high adamantine lustre, and white or greyish white color, turning to pale green and blackish. It is both massive and crystallized, sometimes acicular, when its lustre is pearly and sometimes earthy.

51.—*Tinstone, or Oxide of Tin*, occurs crystallized in obtuse octahedra and very brilliant, color brown or black. It can be distinguished by its weight, which is a little greater even than lead—lead being

6·3; Tin 6·4; Iron 3·6 and 4·5; Copper 5·8; Quartz 2·6; Zinc 4·2; Antimony 4·6, &c. It does not yield to the knife, and scratches glass. When of fibrous structure, it is called Wood Tin; when of gravelly, Stream Tin. It is always found in primary rocks, never in any of later age; as in Granite and Primary Slate, and in Cornwall in porphyry or elvan dykes. In the veins with it is generally Quartz.

52.—*Antimony* is known by its Tin white color; its structure is granular, foliacious, and it has a brilliant lustre. The length of its fibre will distinguish it from lead, than which it is lighter as well as softer, being also brittle. It is indeed the softest metal known, melting even in the flame of a candle, which no other ore does.

53.—*Cinnabar,* or ore of Mercury, is of bright or brownish red, and its streak red, lustre adamantine. It occurs in compact crystalline masses, in patches or encrusting the rock; crystalline form, tabular or six-sided prisms.

It resembles red lead ore or Minium, and *Realgar* (sulph. of arsenic), but these may be distinguished by the orange yellow color of their powders.

54.—*Arsenic* does not often occur pure in nature, and mostly forms kidney-shaped laminated compound masses, which are compact and finely granular in the fracture. It is soft, but brittle. Its color is bluish white or steel grey with a brilliant lustre. A little less heavy than lead, being 6.

55.—*Platinum,* a remarkable and most useful metal, of very high specific gravity, 21; and of high price, Silver, Platinum and Gold being relatively as 1, 3, and 15 in value; is of whitish iron-grey color, and is usually found in cubical crystals like Gold, and often with that metal, in sandy ground and the sands of rivers, in the form of small laminæ and grains.

56.—*Silver* is found mixed with many other metals and ores, and is known by its white color and high lustre.

57.—The *Sulphuret of Silver,* the richest and most abundant ore of it, may be cut and flattened out like Lead, which serves to distinguish it from other similar ores. Silver is not found like Gold, granular and in sands, although its crystalline form, the octahedron, is the same; but in the primitive rocks granite, gneiss, mica, slate, &c. Its specific gravity is 10·4. Gold is 14·8 unhammered.

58.—The PRECIOUS STONES may be best distinguished by their crystalline forms, color and hardness. Thus, for instance, if it is remembered that the *Diamond* crystallizes in the octahedral form, and Quartz in the hexagonal, it is impossible to mistake, as has sometimes happened, the one for the other, even at the first glance.

While if further examination be necessary, although both will scratch glass, yet a Topaz, Ruby, or Sapphire (*i. e.*) Corundum, will scratch the Quartz, but will not touch the Diamond. The specific gravity of the Diamond is 3·5, and the usual way of calculating the value of the *rough* stone, is to square its weight in carats (the carat being rather more than 3 grains) and multiply that by £2, or if the stone be cut, then square and multiply by £8. The "rose" Diamond is mostly formed out of the octahedral forms, the "brilliant" from the pyramidal octahedron.

59.—Of the other principal precious stones, it will not be necessary to say much. They divide themselves chiefly into the silicious and aluminous classes. Of the former are, first, *Rock crystal,* which occurs in six sided prisms.

60.—The *Cairngorm;* yellow rock crystal. The *Amethyst,* purple rock crystal, whose value is not great, being about 8 to 15 shillings the carat, and stones of 10 carats £5 to £6.

Cat's Eye and Jasper, other forms. The latter resembling Red Porphyry and Agate.

61.—Crystallized Silica occurs frequently mixed with uncrystallized, forming gems, which cannot be made artificially. Such are *Opal,* which is highly valued, and occurs in Trachytic rocks. *Chalcedony,* found in amygdaloid and alluvial deposits, and in various forms as *Onyx* when in layers adapted for Cameos, *Cornelian* when red, (or yellow or brown;) *Chrysoprase* when apple green, from nickel; *Heliotrope* of a dark green with red or yellow spots, from earthy chlorite; *Agate* when in irregular layers, or containing dendritic markings.

62.—*Crysolite* (containing Magnesia) is of blackish green color, and is very abundant in Basalts, usually in granular masses called *Olivine.*

63.—*Crysoberyl* (containing Glucina) is a transparent pale yellowish green, and is rare.

64.—The *Emerald,* also containing glucina, is found in six-sided prisms, and is a very valuable stone, the carat, when the stone is pure, being valued at as much as £4, and stones of six carats £60 to £90. They are found in Quartz, Mica and Hornblende slates. When fainter colored, light greenish blue, sky blue and yellow, and less transparent it is the *Beryl,* or *Aquamarine,* which is cheap, about 5 to 10 shillings the carat. These often occur in prisms nine inches long and an inch thick.

65.—The *Topaz* contains fluoric acid, and is only less hard than the Corundum and Diamond. Its crystals are prismatic. Its usual color is wine yellow, sometimes colorless, bluish green, and reddish, and it may be colored rosy red by exposure to a gentle glowing heat. Its

value is about 10 to 14 shillings the carat, the yellowish stones; the rosy and colorless higher.

66.—The *Garnet* is red. Its crystals (modifications of the cube) have either 12 rhombic, or 24 trapezoid faces. It occurs very commonly in Mica Schists, but is frequently so dull colored externally as not readily to be distinguished.

67.—*Tourmaline* (containing Boracic acid) is in Hexagonal crystals, usually dark colored, but sometimes red, green and blue, when it is more valuable.

68.—*Labradorite*, gleaming with blue, yellow green and copper-colored reflexions, and *Lapis Lazuli* owing its beautiful blue colored Ultramarine, to a compound of sulphur which it contains, are other stones of this family.

69.—Of the ALUMINOUS kind, we have first the *Corundum*, which includes the *Ruby* and *Sapphire* stones, essentially the same, being crystallized alumina, but differing in color, the former being red, the latter blue. They are the hardest of all stones except the Diamond, and are four times heavier than water. Red Sapphires or Rubies, also called Carbuncle, are prized far more highly than the blue. A perfectly pure deep carmine red Ruby often exceeds in price a Diamond of the same size. The average price of stones of one carat is £2-10; of two carats £7-10; of three, £20; of five, £40; of the Sapphire the average price is £1-5 the carat, but stones exceeding 6 or 7 carats, have fetched above £60.

The crystallized form of these stones is usually six-sided prisms, and some of the best are obtained from Ava, from the Capelan Mountains, 12 days' journey from Syrian in Pegu (thought by some to be the ancient Ophir), also in Ceylon at Matura and Suffragang; and in the Carnatic, at Mysore.

The compact form is generally called Corundum, and is often rough, dull, and opaque. It is obtained in Ceylon and at Canton.

70.—*Emery* is the granular variety. It is found in India, and occurs chiefly in Gneiss or Mica slate, talcose rock and even in granular Limestone, associated with Oxide of Iron. The color is smoke grey or bluish grey; fracture imperfect.

71.—The *Spinelle* is often confounded with the Ruby, but is of different composition, as it contains Magnesia. Its form of crystal is also different, being octahedral. When of equal size, it is heavier than the Ruby. Its color is usually lighter, being a rosy red. Its price, when without defect and above 4 carats in weight, is about half the price

of a Diamond of the same weight; lustre vitreous; streak white; brittle. It is insoluble in Muriatic Acid, but in powder partially soluble in Sulphuric Acid. It is found in Ava and Mysore, and embedded in Dolomite, in Gneiss and Granite in Ceylon.

72.—The *Turquoise* is opaque, and of sky blue or greenish blue color. Its lustre is waxy. It is composed of Phosphate of Alumina, colored by Copper. It is found chiefly in Persia in cracks in aluminous iron stone, and in veins in silicious rocks; also in loose gravel. Fine stones as large as a pea, fetch 12 or 15 shillings. It is a little harder than Apatite, less so than Felspar. Its blue color is lost by the action of Muriatic Acid, in which it is soluble. It is amorphous, or in no regular crystalline form.

73.—It will of course be understood that all rocks, and metallic ores particularly, assume an infinite variety of colors and combinations and that the observer must be prepared, not only to find specimens which will puzzle him in the field, but which it will not be easy sometimes to determine with accuracy, even in the closet, and with the aid of such additional proofs and tests as may there be available, and which will hereafter be mentioned. He will find the greatest assistance, as before stated, from a Geological Cabinet, such as he may purchase for 50 Rs. from Mr. Rose, of No. 1, Drummond Street, Edinburgh, or of Mr. Tennant, 149, Strand. Such a Cabinet of Mr. Rose's, is not only highly instructive, indeed it may be said necessary, to the student, but is also entertaining to the curious, and a handsome little piece of furniture.

74.—In the following table, I have endeavoured to arrange the different Rocks and Minerals under the simple heads which naturally first suggest themselves to a beginner, *viz.*:

Flint Stones | Clay Stones | Lime Stones

and Metals, to which are added a few coming under the heads of earths; salts of soda and potash; and inflammable fossils.

75.—Such a classification, it is necessary to inform the reader, is opposed to modern arrangements, which, with more accuracy but greater confusion to a learner, class minerals and stones under such heads as Silico aluminates; Hydrous or Andydrous aluminous Silicates, &c. &c.

76.—The reader will therefore note, that the table is not strictly correct; that it is given merely for the convenience of a general classification in the mind of the beginner; that it necessarily contains errors when rigidly examined; and that, if perfect accuracy be required, the modern classifications of good authorities must be consulted.

Classification Table of Earths, Stones and Metals.

EARTHS AND STONES.	FLINT GENUS.	Quartz, ...	Rock Crystal, Amethyst, Cairngorm, Chert, Opal, Onyx, Heliotrope or Blood-stone, Jasper, Flint, Horn-stone, Chalcedony, Cornelian, Crysoprase, Agate, Float-stone, Bilin, Tripoli, Touch-stone, Cat's Eye, Sand-stones.
		Felspar, ...	Andalusite, Adularia, Leucite, Orthoclase, Labradorite, Clink-stone or Phonolite, Albite.
		Trap, ...	Basalt, Green-stone, Diorite, Amygdaloid, Greywacké, Granite, Gneiss, Porphyry, Trachyte, Lava, Diaspore, Pitch-stone, Obsidion, Pumice.
		Hornblende, or Amphibole, ...	Sienite, Actinolite, Tremolite, Jade, or Axe-stone.
		Pyroxene, or Augite, ...	Hyperstene, Asbestos, Diopside, Mountain or Rock Cork, and Rock Leather.
		Zeolites, ...	Wavellite, Phrenite, Natrolite, Stilbite, Henlandite.
		Garnet, ...	Cinnamon Stone, Idocrase, Epidote, Crysolite, Olivine.
		Combinations of Silica, with Glucina, Fluoric Acid, &c.	(Glucina) Euclase, Emerald, Beryl—(Fluoric Acid) Mica and Topaz—(Sulphur) Lapis Lazuli—(Boracic Acid) Tourmaline or Schorl.
	CLAY GENUS.	Clay, ...	Kaolin or Porcelain Earth, Loam, (5 to 6 p. ct. Lime) Potter's Clay, Lithomarge, Clay-stone, Fuller's Earth, Alum-stone, Stourbridge or Fire Clay, Bituminous Shale, Drawing Slate, Whet Slate.
		Corundum, ...	Spinel, Sapphire, Ruby, Carbuncle, Emery, Turquoise.
		Magnesia, ...	Chlorite, Native Magnesia or Periclase, Meerschaum, Epsom Salts, French Chalk, Serpentine.
		Talc, ...	Steatite or Soap-stone, Verd Antique, Pot-stone or Talcose Slate.
	CALCAREOUS GENUS.	Lime, ...	1. Carbonate of Lime or Calc Spar, Chalk, Marble, Verd Antique, (when mixed Serpentine and Lime-stone); Dolomite, (when Carb^{e}. of Magnesia is mixed with it); Stink-stone, Cipolino (where Talc is mixed); Marl, (an Earthy Carbonate with 40 to 50 p. ct. Clay); Hydraulic Lime-stone, (where 10 to 30 p. ct. Clay); Cement Stone, (where Clay proper is still greater); Semi-crystalline Lime-stone, (as Purbeck, Petworth, &c.,) Stalactites and Stalagmites, Arragonite, Oolite, Satin Spar, Argentine. 2. Phosphate of Lime, Apatite, Asparagus Stone, Phosphorite. 3. Fluate of Lime, Fluor or Derbyshire Spar. 4. Sulphate of Lime, Gypsum, Selenite, Alabaster.
	EARTHS.	Baryta, ...	Heavy Spar, Witherite, or Carbonate of Baryta, Sulphate of Baryta.
		Strontia, ...	Strontianite or Carb^{e}. of Strontia; Celestine, or Sulphate of Strontia.
NATIVE SALTS OF SODA, POTASH AND AMMONIA.		Borate, ...	Borate of Soda.
		Carbonate, ...	Carbonate of Soda.
		Nitrates, ...	Nitrate of Soda; Nitrate of Potash.
		Muriates, ...	Rock Salt, Sal-Ammoniac.
		Sulphates, ...	Sulphate of Iron; of Magnesia; Alum or Sulphate of Alumina and Potash; Epsom Salts, (Sulph^{e}. of Magnesia) Glauber Salts, (Sulph^{e}. of Soda.)

Classification Table of Earths, Stones and Metals.—(Continued.)

EARTHS AND STONES.	INFLAMMABLE FOSSILS.	Carbon, ...	Diamond, Anthracite, Lignite, Graphite.
		Sulphur, ...	Native and Volcanic.
		Bitumen, ...	Naphtha, Petroleum, Asphalte, Mineral Pitch; Coal, Brown Coal, Cannel, Splint, Cherry, Caking, Earthy Coal, &c., Jet.
		Amber or Resin,	Amber, Mellite.
			Metals not immediately Oxidizable by Heat.
METALLIC ORES.	METALLIC MINERALS.	Platinum, ...	
		Gold, ...	
		Silver, ...	Antimoniated and Arseniated Silver, Silver Glance, Red, White, Black, Silver, Ore, &c.
			Immediately Oxidizable and reducible by Heat.
		Mercury, ...	Cinnabar, Liver Ore, Horn Ore, &c.
			Oxidizable but not immediately reducible by heat; Ductile and Malleable.
		Lead, ...	Galena, Lead Glance or Sulphuret of Lead, Brown, Black, White Ores, &c.
		Nickel, ...	Sulphuret or Copper Nickel, Nickel Ochre.
		Copper, ...	Pyrites, Grey, Black, Red Ores; Peacock Ore, Azurite, Malachite, Muriate of Copper, &c.
		Iron, ...	Pyrites, Magnetic, Glance, Red, Brown, Black, Hematile, Clay Iron-stone, Reddle, Columnar, Bog, Lenticular, Reniform, Pisiform, &c.
		Tin, ...	Tin-stone, Stream Tin, Wood Tin, Sulphuret, &c.
		Zinc, ...	Blende, Calamine.
			Not Ductile and Malleable.
		Bismuth, ...	Sulphuret, Ochre or Oxide.
		Cobalt, ...	White, Red, Black, &c.
		Arsenic, ...	Pyrites, Red and Yellow Orpiment, Bloom.
		Manganese, ...	Grey, Black, Red.
		Antimony, ...	Native, Grey, Black, and Ochre.
		Tungsten, ...	Wolfram, a Tungstate of Iron and Manganese.
		Chromium, ...	Chrome.

NOTE.—The Felspar, Trap, Hornblende and Augitic Rocks are very much mixed up together. I have thought it best to simplify by placing the chief Volcanic ones in the general class of "Trap" Rocks, although some of these, as Trachyte, Porphyry and Pumice, are chiefly Felspathic in their constitution; others again, as Greenstone and Diorite among the Trap Rocks, consist of Felspar and Hornblende; Albite and Hornblende, &c. Sienite, although so closely allied to Granite, I have placed under Hornblende, because that Rock replacing Mica, is its distinguishing characteristic.

SECTION III.

1.—To the collection and examination of particular specimens, should be joined a general examination of the country through which the observer may be passing. A correct knowledge of this will assist much in preparing him for the nature of rocks and minerals likely to be encountered.

2.—Some standard works on the subject should be read, as Ansted, Dana, or Lyell, &c., &c., but perhaps the most valuable book to study with reference to this point is De la Beche's Geological Observer. In this excellent work are pointed out and explained the numerous methods by which nature is constantly working to change the visible features of the globe we inhabit, and in it instructions are given how best to observe the alterations which may have been effected in former ages, as well as those now actually in progress. The student cannot do better, after acquainting himself with the general principles of Geology from any competent authority, than study this book, which can scarcely fail, from the curious facts it brings together, to stimulate his disposition to look round him, and note how many and great changes nature is silently yet rapidly accomplishing.

3.—If the traveller be unable to visit mountain ranges visible from a distance, he may yet draw some conclusions as to their probable formation from the general appearance. Thus calcareous formations and Granite liable to decomposition, have very generally rounded summits. Dark walls and precipices would suggest Trap or Basalt slates; and Quartziferous Schists are often pyramidal. Crystalline Schists in sharp needles like the Alps—Serpentine and Trachyte twisted and crumpled. Dolomite (Magnesian Limestone) assumes the form of peaks like Saw-teeth, and Volcanoes would be in the form of blunted cones.*

4.—In his immediate neighbourhood, he should note with care, aided by the means before pointed out, *viz.* hammer, penknife, acid, &c. the nature of the rocks; the Strike or direction of the strata

* Captain Newbold, in his summary of the geology of Southern India, notices the frequent occurrence of the Plutonic rocks, as Granite and of Gneiss, in abrupt detached hills, with scarcely any slopes in the middle of plains "causing the not inapt comparison of a table, with tea-cups here and there reversed on its surface;" on such hills are situated the Droogs, or Hill forts of the Deccan, and a similar appearance is seen in Bundlecund.

edges; their Dip; to what point of the compass, and at what angle; and also, if possible, the Cleavage planes.

Wherever sections may be exposed by the excavation of quarries, or by the soil being washed away in the beds of rivers, valuable information will, in all probability, be obtained, and such places should always be searched for.

It is a remark of the great Humboldt that while the forms of organic vegetation vary so much with different climates, those of the inorganic crust of the earth are more independent of it; and that "every where Basalt rises in twin mountains and truncated cones; every where Trap Porphyry presents itself to the eye under the form of grotesquely shaped masses of rock, while Granite terminates in gently rounded summits."

5.—The stratification and super-position of rocks may be most readily discovered by actual visits to such spots, but they may also be determined in moving over an extent of ground by remarking the successive "cropping out" of different rocks. In this way only can a Geological map of a country, the great end of all out-door observations, be prepared.

6.—This is a point of much importance in determining the formation to which rocks belong. For instance a Clay Slate may be met with. This may belong to the secondary as well as the primary formation, and its true age could only be ascertained by observing the strata with which it alternated. If the Clay Slate were simple and unmixed with or not alternating with breccias or conglomerates, it would belong to the primary, but if fragments of primary rocks, as Talc Slate, were found embedded in it, this would argue that it belonged to the secondary.

7.—But the discovery of Fossils, if these can be found, will immediately establish the date of the formation in which they exist. Discoveries are constantly being made in this branch of Geology, and are of the first importance. They thould therefore always be among the chief inquiries and researches of an observer.

8.—It is necessary to distinguish between Fossils and Petrifactions.

Fossils, as signified by its derivation from the Latin word "*Fossus*," dug out, signifies organic remains embedded in rocks.

Petrifactions are organic remains which have become wholly or partially turned into Stone, which is usually of two kinds. Either formed by the deposition of Lime, in which case they effervesce with acid, or by a similar deposition or infiltration of Silica, when they are much harder and do not effervesce; of the former kind are Stalactites generally, and of the latter the Burmese, Egyptian, and Icelandic Petrifactions of wood, &c.

9.—The accompanying abbreviated synoptical table may assist, if kept constantly in view, in arranging in the mind of the Geological reader, in a simple and practical manner, both the successive arrangement of the usual Geological formations, and the nature of the Fossils which may be expected in each, or *vice versâ* the formations from the Fossils. It will be observed how these are as a general rule, not however without important exceptions, gradually developed in accordance with Geological Theory through the different orders of Creation, from the lowest to the highest.

10.—To the Geological Table, I prefix a Table of the natural orders of Creation of the Animal Kingdom as given by Cuvier, and a Table of the Natural system of Botany, according to Decandolle, containing only those of the orders most commonly occurring.

These will, I trust, help to explain to a beginner some of the terms of the Animal and Vegetable Kingdoms used in the Geological Table, and will, in other respects, I hope, not be without use.

Table of the Natural Orders of Creation from Cuvier.

Sub-kingdoms.	*Class.*		*Instances.*
RADIATA.	XXII	Porifera, ...	sponges.
	XXI.	Polypifera ...	corals crinoids or sea-lilies.
	XX.	Acalephæ, ...	or sea nettles and jelly fishes.
	XIX.	Echinodermata,	star fish.
	XVIII.	Polygastrica,	animalcules, infusoria.
MOLLUSCA.	XVII.	Tunicata.......	leathery coated, and fixed to rocks spouting water.
	XVI.	Conchifera, ...	Mussel, oyster.
	XV.	Gasteropoda,	paper nautilus. limpet or patella, helix or snail, murex, cowry, Venus' ear, chiton, limax or slug.
	XIV.	Pteropoda, ...	clio.
	XIII.	Cephalopoda,	cuttle fish.
ARTICULATA.	XII.	Entozoa, ...	Guinea worm, tape worm.
	XI.	Rotifera.	wheel animalcules.
	X.	Cirrhopoda, ...	Barnacle.
	IX.	Annelida, ...	worms, leech.
	VIII.	Myriopoda, ...	centipede.
	VII.	Crustacea, ...	Lobster, crab &c.
	VI.	Arachnida, ...	Spider, eight legs.
VERTEBRATA.	V.	Insects, ...	having breathing apparatus and six legs.
	IV.	Fishes.	
	III.	Reptiles.	
	II.	Birds.	
	I.	Mammalia.	

NOTE.—The 22 "Classes" are again divided into orders, families, Genera, and Species.

11.—The reader will understand that in the later formations all those remains previously mentioned, may, as a general rule, be found, and that the object of the Table is to show the Fossils belonging to each era, and the earliest strata in which each has as yet been found. And although in these a progressive advance may be traced, as before observed, from the lower to the higher orders of Creation, this should not be confounded with the so-called Theory of Developement, of German authors and others.

12.—The unsoundness of that Theory, and its inconsistency in many points with Geological facts, have been sufficiently pointed out by Mr. Hugh Millar in his "Footsteps of the Creator," (a delightful book to the Geological reader,) as well as by other scientific writers. Instead of the earliest periods of Fossil discovery being filled with crustacean and molluscan remains only, and "utterly devoid of fish," specimens of "vertebrata," fish of the highest class, have been found in the Silurian (the earliest of Fossil bearing formations), and lignite of a cone-bearing tree in the base of the Old red sandstone.

13.—Mr. Millar remarks thus:—"The fact that fishes and reptiles were created on an earlier day than the beasts of the field and the human family gives no ground whatever for the belief that 'the peopling of the earth was one of a natural kind requiring time,' or that the reptiles and fishes have been not only the predecessors but also the progenitors of the beasts and of man."

14.—On the contrary he says, rather more argument may be deduced to support a Degradation than a Developement Theory. "There was a time when the Ichthyic form constituted the highest example of life, but the seas during that period did not swarm with fish of the degraded type (as the sole and the flounder); there was in like manner a time when all the carnivora and all the herbivorous quadrupeds were represented by reptiles, but there are no such magnificent reptiles on the earth now as reigned over it then; there was an after-time, when birds seem to have been the sole representative of the warm-blooded animals; but we find from the prints of their feet left in sandstone that the tallest men might have

"Walked under their huge legs and peeped about."

Further there was an age when the quadruped mammals were the magnates of Creation; but it was an age in which the sagacious elephant, now extinct save in the comparatively small Asiatic and African circles, and restricted to two species, was the inhabitant of every country of the Old World, from its Southern extremity to the foreign shores

of the Northern Ocean; and when vast herds of a closely allied and equally colossal genus occupied its place in the New."

15.—Besides Fossils more or less complete, there are many other marks of organic remains which should be carefully watched for. Such are Coprolites, the excrement of extinct animals, round masses, sometimes simply like pebbles, sometimes convoluted and containing the scales of fishes, &c. Also the teeth and palates of fishes, the foot prints of animals, sea, ripple and rain marks. These, and all or any marks indicating organic existence, should at all times be searched for, and, if possible, preserved.

16.—They are useful, not only in determining the age and position of the deposits containing them, but also in arranging the layers of Stratification or "bedding," as distinguished from Cleavage; points which are often difficult to make out.

17.—Joints are parallel lines or separations in rocks, dividing a mass into layers on a large scale.

18.—Cleavage is generally supposed to be due to some electric influence, acting upon the rock after its deposition, and dividing it by a vast number of fissures and crevices into planes, similar to slates.

19.—As these three; Stratification, Joints and Cleavage are sometimes all in different directions, rocks are found marked with innumerable intersecting lines, and, as before stated, it is not easy always to determine which are the lines of Stratification, and which those of Cleavage and Joints.

20.—If the observer should, in a mountainous country, find shells at a considerable elevation, as is the case in the Himalayas, he will recollect the circumstances under which these have come into that position, with reference to the rocks or strata found at a higher and lower elevation above and below them, that is, that the highest parts or peaks are probably the igneous or primary rocks obtruded through the secondary, which are hence immediately below them and contain the shells; and that the lowest strata are the Tertiary or Diluvial, arising from the attrition and wearing away of the other two. Hence in ascending the mountains, he would come to first the Tertiary, then the Secondary, finally the Primary Granite summits.

21.—M. Elie de Beaumont is of opinion that the age of any mountain chain may thus be determined, on the supposition that its elevation must necessarily have occurred between the period of the deposition of the vertically elevated strata (the secondary) and that of the horizontally inclined strata running at the base of the mountains.

SECTION IV.

1.—THE various rocks of which the Earth is composed have, from the earliest ages, been subject to natural operations and actions, which have very much modified, and continue daily to modify, their appearance and arrangement.

2.—Some comprehension of these is necessary in order to understand the infinite varieties of form, under which rocks present themselves. To the chemical reader especially, these operating causes are full of the greatest interest and attraction.

3.—The changes produced on the immediate surface by these natural actions, are so great as to complicate much to the practical observer the theoretically simple Geological arrangement of strata of Rocks. Hence it is all the more necessary to take a glance both at the deeper seated agents of change, and at the superficial, and to understand in what way are produced the sub-divisions of the "Superficial Strata" which are presented in a Tabular form at page 34.

4.—Many rocks, especially the Primary, owe their origin to fire, and where volcanoes exist, this creative power is of course still in operation. But even where there are no visible and active volcanoes, earthquakes of more or less violence, and undulating heavings of the Earth's surface, are due to the same power; and these are of great importance as tending to disturb and crack the materials of the Earth's crust, and thus give rise to alterations in the relative positions of the chemical constituents of its mass, as well as giving way for water, both sea and fresh, to percolate and carry in dilution various Salts and Earths to mingle with others in their neighbourhood.

5.—This, *viz.* chemical combination and consequent reciprocal action, is a force which is constantly in operation, and joined to Voltaic Electricity or Terrestrial Magnetism, is always at work effecting the most important operations and changes.

6.—It is perhaps not sufficiently watched from its being a silent and slow workman, but the study of its causes and effects is worthy of the most attentive consideration of the observer.

7.—Let him beware, however, of running into the German extreme of attributing to it *Creative* power. For the disproval of this doctrine, supposed to be supported by some experiments of Messrs. Crosse and Weekes, I cannot do better than refer again to Mr. Hugh Millar's admirable work before-mentioned, the "Footsteps of the Creator."

8.—While the observer notes the infinite variety of Fossils which are presented by the Geological formations, the fish in ancient periods heterocercal, that is, with the fan of the tail altogether on the lower side of the central bone, now homocercal, or with the fan equally divided above and below; the ancient shells of the murex species with the opening (when held perpendicularly) to the left hand, those of modern eras opening to the right; many species of ancient times altogether extinct, and shells and animals of a totally different kind now existing on the Earth from what were formerly found there, he will see the truth of Mr. Millar's observation, that "nothing on the one hand can be more various in character and aspect, than the organized existences of the various circles and periods; nothing more invariable on the other, than the results of chemical or electrical experiment." "The vast variety of these existences speak not of the operation of *unvarying laws*, that represent in their uniformity of result, the unchangeableness of the Divinity, but of *creative acts*, that exemplify the infinity of his resources."

9.—Besides these there is a very important cause of change in the appearance of rocks, *viz.* Igneous contact. This has caused the formation of some of the earlier strata, which are supposed to have been more than others exposed to this agent of change; hence called Metamorphic rocks. Metamorphism being another name for igneous contact and its consequences.

10.—The rocks termed Plutonic (Granite, Porphyry, Serpentine, &c.,) are supposed to have been forced out through fissures on to the surface merely in a thick and softened state. Those called Volcanic, as Trachyte, Basalt, Lava in a more complete state of fusion.

11.—According to the manner in which these have cooled, slowly or quickly, under pressure or otherwise, is their appearance changed, and in like manner that of any rocks with which they may have come in contact in their melted state.

12.—Fused Volcanic rocks, if cooled *rapidly*, form into a black glass; if the cooling be *slow* into a stony mass of granular crystalline structure; this process may be witnessed in the laboratory.

13.—Carbonate of Lime, when fused under great pressure, does not lose its carbonic acid. If the process be by the dry method, it becomes

granular Marble ; if by the humid, Calcareous spar and Arragonite are produced.

14.—Chalk is thus converted into marble perhaps by Basalt. Coal into Anthracite by Trap. Common Schist into a bluish black glistening roofing Slate. Gneiss is generally supposed to be produced by the metamorphic action of Granite, which coming into contact with a calcareous marl, might change it into Mica Schist, and finally into Gneiss.

The same with Argillaceous Schist. It is observed that, " it would not be surprising to meet with a fragment of Gneiss formed on the walls of a smelting furnace, which was built of argillaceous slate and Gray-wacké," this last containing the fragmentary constituents of Granite.

15.—Quartz is sometimes found in unusual places, in great masses, and at great heights, and may have been produced thus from Sandstone.

The discovery of Diamonds in solid Silica and Sandstone, where they are found like Garnets in Mica Slate, and Argillaceous Schist in contact with Basalt, may also be due to the same causes.

The Carrara marble quarries are, in fact, strata of calcareous sandstone thus converted.

16.—These are but a few of the extraordinary changes which this powerful agent effects. They may be most clearly observed in the neighbourhood of the surfaces of the contact, close to which the change effected is often clearly observable, while as a greater distance intervenes it becomes less so.

17.—Another agent of nature by which great changes are operated, but which has not until of late years attracted much attention, is the extraordinary and universal diffusion of Microscopic Infusoria. These invisible animalculæ pervade the whole of creation. They are found in the ocean and in the warm winds encountered at sea, and hitherto supposed to bear clouds of sand only from the deserts of Africa. They redden the snow, which covers the highest mountainous lands, and they exist in deep caves and fissures where chemically charged waters only could have infiltrated. In the blood of animals and the tissue of plants, they have been found by Ehrenberg. In Glaciers and in hot springs; and so incalculable are their numbers, that their silicious shelled organisms form, Humboldt says, in some humid districts, subterranean strata many fathoms in depth. In China dust falls of this kind, which are considered fertilizing, are said to amount to 10 grains the square foot, by Dr. McGowan.

M. Ehrenberg has shown that in some Infusoria, the extraordinary power of division and development of bulk are so great, that an animalcule invisible to the naked eye, can in four days form two cubic feet of the Bilin polishing slate.

18.—Let it be noted then that there are four grand forces constantly operating upon, and changing the state of, the Earth's surface: 1st.—The erosive effects of climate and rain, whence arises stratification. 2nd.—Subterranean disturbances and earthquakes, whence originate joints, faults, general elevations and depressions of the surface. 3rd.—Terrestrial Magnetism, the cause of Cleavage and of the crystalline formation of minerals, precious stones, as well as of the distinctive structural formation of many kinds of rocks; and 4th.—Metamorphic change, from igneous contact.

19.—It is impossible to say that any one of these deserves attention more than another. All are highly important, and all in constant operation. Even of earthquakes which, as regards universal occurrence, might be supposed to be least so, Humboldt says that in some places, *viz.*, near Aleppo, Mount Cenis and Cincinnati in America, earth shocks have been of hourly occurrence for months together. In Peru they occur about once a week, and are looked upon with no greater wonder than a shower of hail in the temperate Zone, and it is Humboldt's opinion that—"If we could obtain information regarding the daily condition of all the earth's surface, we should probably discover, that the earth is almost always undergoing shocks at some point of its superficies, and is continually influenced by the reaction of the interior on the exterior."

20.—It should also be borne in mind, when considering the constant operation of this disturbing force, that the focus of disturbance is shown by a variety of circumstances to be frequently very deep seated. Imperceptible disturbances or undulations frequently take place; subterranean noises without motion of any kind. Earthquakes in alluvial countries, as Holland and Egypt; and others again, which are propagated to great distances, crossing immense mountain ranges (which are supposed to be elevated over fissures in the earth's surface) in their track.

21.—Certainly not the least interesting of the four disturbing agents mentioned, however, is the third, when we consider that to this we owe the formation, not only of the useful metals, but of precious stones and jewels. The existence of Electro-Magnetic currents in the interior of the Globe is no longer a matter of doubt, but their direction is not so certain. M. Ampère supposes Electric currents to be constantly

circulating from East to West. M. Bécquerel considers that at a certain depth in the earth, a multitude exist, circulating in different directions. Mr. Hopkins that they range from pole to pole in all the orbs of Creation, their traces or marks being apparent even on the face of the full moon, through a telescope, and that to them are, in fact, due the phenomena of ocean currents, of heavy tides and bores in bays opening Southward, and the converse, *viz.*, no perceptible tides in closed seas or such as range East and West, as the Baltic and Mediterranean; so also the general conformation of land on the surface of the Globe in large peninsulas with their apices pointing Southward, as the continents of America, Africa, and Hindostan.

22.—Planes of cleavage have been produced artificially by Mr. Fox, by long continued Voltaic Electricity, through masses of Clay, and he found that the planes of the laminæ were formed at right angles to the direction of the Electrical forces. The same results have been obtained by Mr. Robert Hunt at the Museum of Economic Geology.

23.—Rocks are also much influenced in their structural formation by this cause. The globular or columnar structure of Basalt is due to its cooling from a molten state under crystalline influence, and Coke also, during its baking, undergoes a kind of crystalline transformation.

24.—Solid bodies present themselves, as has already been said, in describing the External " Form," with two characteristics. Either they are crystalline or amorphous.

Time and freedom of motion are necessary for the particles of bodies, in order to effect the formation of crystals. Liebig says:—If we force a fluid or a gas to become suddenly solid, leaving no time for its particles to arrange themselves, and cohere in that direction in which the cohesive attraction is strongest, no crystals will be formed, but the resulting solid will have a different color, a different degree of hardness and cohesion, and will refract light differently. Thus we have Cinnabar (Sulphuret of Mercury) as a red and a jet black substance (the former when crystallized.) Sulphur, a fixed and brittle body crystallized; and soft semi-transparent and ductile, when amorphous; glass both as a milk white opaque substance so hard that it strikes fire with steel, and in its ordinary and well-known transparent amorphous state with a conchoidal fracture. These dissimilar states and properties of the same body, are occasioned in one case by a regular, in the other by an irregular, arrangement of its atoms; one is crystalline, the other amorphous.

25.—Applying these facts to natural productions, we have reason to believe that Clay Slate and many kinds of Greywacké, are amorphous,

Felspar, Mica Slate, or Granite—as Transition limestone is amorphous marble; Basalt and Lava mixtures of amorphous Zeolite and Augite. Anything that influences the cohesion, must also in a certain degree, alter the properties of bodies.

26.—Mechanical motion as well as freedom of motion, influences crystallization, as is well known in the case of Water, which may be reduced if in a state of perfect rest far below the freezing point without solidifying, but when in this state, the mere touch of a needle is sufficient to convert the whole mass into ice in a moment. In order to form crystals, the smallest particles of bodies must be in a state of motion; they must change their place or position to be able to arrange themselves in the direction of their most powerful attraction. Many hot saturated saline solutions deposit no crystals on cooling, when allowed to remain completely at rest: the smallest particle of dust or a grain of sand, however, thrown into the solution, suffices to induce crystallization.

27.—Wrought Iron is converted by feeble and constantly repeated strokes of a hammer into crystalline and brittle cast iron, the atoms alter their position, and through the influence of the mechanical motion imparted to them, arrange themselves in the direction of their most powerful attraction. This phenomenon is manifested more or less speedily in the iron axles of locomotive engines and travelling carriages, and becomes the cause of accidents which cannot be foreseen.

28.—Heat exercises a still more evident effect upon electricity. Thus, when a solution of common salt in water is exposed to a very low temperature, the salt crystallizes in fine large transparent and pellucid prisms, which contain 38 per cent. and upwards of water in chemical combination, whilst the crystals of the same salt formed at common and higher temperatures are always anhydrous, or without water in chemical combination; upon the slightest touch the hydrated crystals lose their transparency and assume a milky appearance; if placed in the palm of the hand they deliquesce and are converted into a mass of small cubes of anhydrous common salt.

29.—When carbonate of lime crystallizes from its solutions in cold water, its particles arrange themselves into the form of the Iceland or doubly refracting spar; when from hot water we obtain it in the form of Arragonite: both these minerals, although so diverse in their crystalline forms, rhombohedral and prismatic hexagonal, so different in hardness (3 and 3.5), specific gravity (2.7 and 3), and power of reflecting light, contain nevertheles absolutely the same proportional amounts of carbonic acid and of lime.

It is still more remarkable that if we expose a crystal of Arragonite to a feeble red heat, that is to a heat of a higher degree than that at which it was formed, a commotion or movement takes place throughout the whole mass of the crystal, and without the slightest alteration occurring in its weight, the entire crystal swells up, presenting the appearance of a cauliflower, and becomes converted into a heap of powder, composed of minute crystals, each of which exhibits the rhombohedral form of common calcareous spar. Phillip says—" the specific gravity of a crystal of Arragonite, is reduced by ignition to that of Calcite."

30.—To the same power of crystallization is also due the adjustment into layers and nodules of the parts of many rocks, as shown by M. De la Beche. In this way Lime, Silica, Iron, Gypsum, &c., are aggregated and deposited.

31.—Regarding this species of action, the Chevr. Bunsen writes—" Their deposition is owing to the fact that has not hitherto been sufficiently regarded in the explanation of Geological phenomena, *viz.*, that substances crystallizing from solutions, are more readily deposited on a surface identical with their own (although at a considerable distance from the limits of their solubility) than on substances different from themselves."

32.—The filling of fissures is effected by the infiltration of saline solutions, or solutions containing the bases of the salts, earths, and alkalies, into crevices formed as previously stated, and their subsequent crystallization under evaporation or decomposition under electric influence.

33.—The increased heat and pressure occurring at great depths in the earth are favorable to these processes. Carbonic acid would, in such cases, be driven off from solutions of the Carbonates, and Silica would become more readily soluble; but this is a branch of Geology in which much remains to be discovered, and the student will perceive that a knowledge of chemistry is absolutely necessary to its comprehension.

34.—Not only are the metals thus deposited and infused into veins, but by the use of Boracic acid as a solvent instead of water, M. Ebelmen has succeeded in producing, by crystallization, Rubies, Sapphires, Chrysoberyl, and Emerald ; and even Diamond dust, as well as Garnets, Idocrase, Olivine and Augite, have lately been manufactured.

The manufacture of cheap and equally good artificial Ultramarine, which is due to the chemical analysis of the stone lapis lazuli, from which the color was always formerly made at a high price, is another instance.

35.—For the common substances entering into the composition of the more frequently occurring rocks, the materials are derivable from the surface of the earth, more readily than might at first be imagined.

Lime is constantly being carried in solutiou by water as the bi-carbonate, but when circumstances arise, as from heat or exposure, by which the Carbonic acid in excess is evaporated, the remaining Carbonate of Lime *being insoluble* is deposited. Hence arise the petrifactions, and the various stones having Lime as their cementing material.

36.—Silicic acid, perhaps the next most important cementing material, is, as will be seen in the chemical part of this work, a very different substance from Silica or Flint,—The latter being hard and gritty, while the former is soft and gelatinous. Silica is insoluble altogether in water or the acids, but can be reduced to a fused state by heat with the alkaline carbonates. In this state, if diluted with water and then evaporated, the Silicic acid *becomes insoluble* and is deposited. Combining again with Oxygen, when infused into earthy or organic substances, it would harden them into the flinty rocks and combinations so frequently met with.

37.—This formation of Silica with which, in chemical analysis, the student will become familiar, is seen in a natural state in the Geyser springs in Iceland, where Professor Bunsen remarks, it is dissolved by alkaline carbonates, and that " no trace of Silica is precipitated on the *cooling* of the water, and it is only after the evaporation of the latter, that Silica is deposited in the form of a thin film on the moistened sides of the vessel, where evaporation to dryness takes place, whilst the fluid itself is not rendered turbid by hydrated Silica or Silica combined with water, until the process of concentration is far advanced."

38.—Silicate of Potash is frequently in solution in water in nature, and if in this state it encounters Carbonic acid, the latter combines with the Potash, and the Silica being set free, is deposited exactly as Lime is under similar circumstances. The presence of Silica in Limestones is thus accounted for by Dr. Lyon Playfair.

39.—The sap of all vegetation, particular grassesand shrubs, produces Silica, and their ashes Potash; and decomposing Granite supplies in abundance the Silicate of Potash; other igneous rocks also supply the Silicate of Soda, which readily parts with its alkali to free Carbonic Acid and deposits the Silica. Silica is also stated by M. Bischoff to be carried off by steam at high temperatures.

40.—Silicic Acid, the most frequently occurring of the earths in vegetation, is, as has been said, quite insoluble in water, except in combination with an alkali, and being actually found in straw combined with

Potash, as also in the stems of the grasses and reeds especially, it may be inferred that alkalies are the means by which this most important substance is rendered available to growing plants. Nature, it will be observed, thus effects what the chemist in his laboratory accomplishes by means of intense fusion in the furnace, *viz.* the solution of that intractable substance Silica with the alkalis.

41.—Again the chemist obtains the re-deposition or precipitation of his Silica by evaporation. Nature effects this, but not so rapidly, by means of slow or secondary electrical action. M. Becquerel found by experiment that "to obtain an insoluble crystallized substance by electro-chemical re-actions, it is sufficient to make it combine with another, which is soluble, and afterwards operate by means of very slow decomposition." This is found to be the most efficient means of producing the desired result, *viz.*, the crystallization and deposition of many substances and salts; indeed M. B. remarks that "all the chemical actions which lead to these compounds could only have arisen from certain electrical influences possessing little energy; for if we operate with apparatus, the action of which is too strong, all the elements are isolated, and no combination is possible."

42.—M. Becquerel produced by these means the oxides of Copper and Zinc; the sulphurets of Silver, Copper, Tin, Lead, Iron, &c.

Not only are substances thus produced in regular and complete crystallized form, but it has been found that when the particles of the crystallizing substance are less abundant, the crystals are less completely formed, so that what appears amorphous or massive Quartz, &c. may in like manner be produced.

43.—The ashes of burnt vegetation produce the metallic oxides in considerable quantity; and Iron, a very commonly diffused cementing material, might thus be obtained in situations where its appearance would be otherwise unaccountable, particularly in tropical countries where annual and extensive conflagrations sometimes occur from superabundant jungle, dried by long continued summer heats. The occurrence of Iron, however, in many places where it could least be expected, as in Aerolites, which are nearly pure Iron, is a phenomenon which has yet to be explained, and it may easily be imagined that it is no easy task to account for the fact of many tons of pure Iron falling in one solid mass from the atmosphere.

44.—Phosphate of Lime, another cementing material in rocks, is acted upon by water and Carbonic Acid in a similar manner to the Carbonate, and being readily derived from bones, as well as fœcal and coprolitic matter, is more generally diffused through rocks, than was at one time supposed.

45.—The reader may thus have a general idea of the means by which nature forms the materials of the earth beneath his feet and around him; and I trust the interest of the subject may excuse my having said so much upon it, but if he is desirous of acquiring more than merely a vague idea; if he wish to determine with any degree of certainty, the nature of the rock, and the quality of the mineral which he finds or may have brought to him, he will see that it is absolutely necessary, that he should be able to analyze them by some of the Chemical processes, which we shall in the 2nd Part proceed to give him.*

46.—The following Table of Superficial Strata (from Chambers) is that alluded to at the beginning of this Section. After what has already been said upon modifying natural actions, but few remarks upon it will be necessary, and with these I shall close the subject.

ENLARGED TABLE OF SUPERFICIAL STRATA.

AGENCIES.	Nature of Accumulations.
DETRITAL.	Erratic blocks or boulders; dark tenacious clays; Ossiferous gravels, sands and pebbly clays; Ossiferous caves, fissures and breccia.
MARINE.	Raised or ancient beaches; Sub-marine forests; Marine silt, Sand drift; Shingle beaches, &c., Sub-marine deposits and accumulations.
FLUVIATILE.	Terrace deposits on valley sides, marking successive water levels, and distinct from general oceanic levels, valley deposits consisting of river sand, gravel, silt, &c.; Deltoid or Estuary deposits, ancient and progressive.
LACUSTRINE.	Sites of ancient lakes now silted up with various debris; Marls, such as shell, clay, and calcareous marls; Lacustrine silt and accumulations now in progress.
MINERAL & CHEMICAL.	Calcareous—Calc tuff, sinter (or deposit from solutions) travertine, stalactites and stalagmites, silicious and aluminous deposits from springs, &c., Saline and Sulphurous deposits from springs, from the sea, volcanoes, &c. Bituminous exudations, pitch lakes, &c.
ORGANIC.	Peat mosses, jungles, vegetable drift. Animal; shell beds, coral reefs, &c., primitive earths with admixtures of organised matter.
VOLCANIC.	Earthquakes, elevations and depressions caused by. Volcanoes, elevations, disruptions and other changes caused by. Discharges and accumulations of Lava, Scoriæ, Dust, &c.

* The subject of Meteorology is intimately connected with that of Terrestrial Magnetism, but it will be as well not to say more connected with it than that it is one which is daily affording surprising sources of interest and discovery to the scientifically disposed, embracing, as it does, such subjects as the upper and under currents of the atmosphere, the laws of storms, the Magnetic properties of Oxygen and the purifying ones of Ozone. All these are particularly interesting in Tropical countries, and in all the student will find his chemical knowledge of the greatest use.

47.—The first mentioned formation on the list, that is "Erratic Blocks and Boulders," is one which has caused much variety of opinion as to its origin, and which is sufficiently perplexing to even a skilled Geologist. How much more then to a beginner is it difficult to account for the isolated appearance in plains, sometimes many hundred miles from any similar formation, and even with high intervening hills and ridges, of blocks or enormous boulders of Granite and other rocks.

48.—By some, these are supposed to have been upborne floating in massive Glaciers, which, drifted southward by currents, have dropped them in former ages in the situations where they are now found. Humboldt, however, and others (Leopold Von Buch, &c.,) receive this theory with caution, and are rather of opinion that they have been carried there by the force of the "penetration and violent out-pouring of pent-up waters by the elevation of mountain chains." To support the former theory a great climatal change is supposed. That is, that an Arctic climate at the Tertiary Period intervened between the Tropical one of the Carbonaceous Epoch and the Temperate clime of the present day.

49.—In the same manner Humboldt ascribes the formation of some conglomerates to the "friction of the elevated rock (during the eruption of molten volcanic matter) against the walls of the fissures," and that this, and not the erosive force of a neighbouring sea, "causes the elevated rock to be inclosed by conglomerates of its own matter."

50.—Among the superficial deposits constantly in process of accumulation, there is one not specially adverted to in the foregoing Table, but which might be inserted under the head organic as "Infusorial."

51.—This has been adverted to previously as having formed (on the authority of Humboldt) Subterranean strata many fathoms in depth, but the discoveries of Ehrenberg have shown, as might have been supposed from the universal diffusion of Infusorial life, that this agency is daily and constantly at work, and that many modern formations are due to it.

52.—Among these is the accumulation of banks of silt or sand in river beds at the point where the ocean and river waters meeting, the influence of the latter destroys and precipitates in vast quantities the Infusoria intended only to inhabit the former. The amount in the fresh mud deposited near the mouth of the Elbe due to marine animalcules, is calculated by Ehrenberg at as much as $\frac{1}{4}$ or $\frac{1}{3}$. This subject must needs be one of special interest in such a country as Hindustan, whose rivers opening into the ocean, are on such a scale of

magnitude, and are subject to such great alternating flows from the monsoon floods and ocean bores to which they are subject.

53.—Another species of structure, not specially mentioned in the foregoing Table, but which may be found, especially in India and other tropical countries to be of the utmost importance, is the Concretionary.

This can neither be classed among the Mineral and Chemical nor among the Organic, but is compounded of both; and although of little consequence perhaps in the Geological systems of European temperate climes, will, I believe, be found to be worthy of more consideration in Tropical countries, where the growth and decay of Organic Vegetation is so much more luxuriant and rapid, and where Climatal and Electrical disturbances are so much more active and violent.

54.—The great Humboldt was at an early period desirous of visiting the Equatorial regions, to avail himself of the greater opportunities there afforded for investigating the operations of Nature, and he remarks on the "obstacles opposed in Northern Latitudes to the discovery of the laws of Nature, owing to the excessive complication of phenomena, and the perpetual local variations that in these climates affect the movements of the atmosphere and the distribution of Organic forms," while he says, "the regions of the torrid zone afford the inestimable advantage of revealing to man, by the uniformity of the variations of the atmosphere and the development of vital forces, and by the contrasts of climate and vegetation exhibited at different elevations, the invariability of the laws that regulate the course of the heavenly bodies, reflected as it were in terrestrial phenomena."

55.—The experiments of Messrs. Fox and Hunt, before referred to, and the remarks of Professor Bunsen, show that under a long-continued flow of electrical currents, not only is a fissile structure or lamination produced in a mass of clay, but also a chemical aggregation of some of the constituents of the mass into nodules. When this species of formation is more extensively carried out through the mass it becomes "Concretionary," and in this form resembles certain hard conglomerates or gravels, and two of the most common Indian formations, Kunker and Laterite.*

56.—By itself this circumstance might not be of much importance, but it becomes different when we consider that this rock, once a simple

* Kunker is classed by Ansted in the Drift or Diluvial period with Regur or the black Cotton Soil placed above it.

clay, is, in its advanced and hardened form, not only impregnated with the Salts, Earths and Metals, but even so much so as to become an ore of Iron, by some thought worth smelting.

57.—Whence, lying on the surface as it does, has it obtained these ingredients? This question leads us to a subject of the greatest interest,—it transports us from the Inorganic to the Organic kingdom. It demands an investigation of the constitution of the vegetable kingdom, as well as of the Air and the Water, which, under all circumstances, act upon the Earth's surface, and which, either alone or with the aid of the remaining Element, Fire, act in the hands of Nature so as to produce such permanent and remarkable changes in the crust of the Earth.

58.—If we are to pursue such an investigation,—if we are to endeavour to trace the circle of operations by which the Organic and Inorganic kingdoms are connected; to discover the link which binds man and animals with the immoveable rocks and plants surrounding them—the aid of *Analytical Chemistry* must be sought, and to a few remarks on this most interesting subject, I propose to devote Part II. of this treatise, and in Part III. to consider the practical application of Parts I. and II., or of Geology and Chemistry, to the ordinary circumstances and pursuits of daily life.

PART II.

IN-DOOR EXAMINATION.

SECTION I.

MECHANICAL ANALYSIS.

1.—We will now suppose that the observer has returned home with specimens of soils, rocks or minerals, which he is desirous of examining more closely than could be done out of doors.

Let us take a soil first as the easiest.

2.—The following may be taken as the simplest possible form of analysis for a soil.

In the field to be examined, take earth a little below the surface, from four separate places, about ¼ of a pound from each, mix them together, and again separate them into four quantities of ¼ of a pound each.

3.—Then take one quantity, and expose it to the sun, or before the fire, till completely dry, and turn it over frequently, that it may be well mixed together. Being thus powdered, pass it through a fine sieve, which will allow all the particles of sand and gravel to escape. but which will hold back stones, small fibrous roots, and decayed wood. Weigh the two parts, the fine and the rough, separately, and take a note of each.

4.—The stones and other bulky materials are then to be examined apart from the roots and wood. If they are hard and rough to the touch, and scratch glass easily, they are in all probability Silicious and flinty; if they are without much difficulty broken to pieces by the fingers, and can be scraped by a knife to powder, Aluminous or clayey; or if when put into a wine-glass, and common vinegar (or hydrochloric acid) poured on them, small air bubbles ascend to the top of the liquid, Calcareous.

5.—The finely divided matter, which ran through the sieve, must next be tried. After being weighed, agitate the whole in water, till the earth be taken up from the bottom, and mechanically suspended, adding water till this effect be produced. Allow the whole then to settle for two or three minutes, and in that time, the *sandy* particles will sink to the bottom. Pour off the water, which will then contain the *Clay* in suspension, and the insoluble earth arising from animal and vegetable decomposition.

6.—The *Sand* should be first attended to, and if from inspection, it be thought either Silicious or Calcareous in its nature, the requisite tests may be at once applied.

7.—By this time the mixture in the poured-off water, will have deposited at the bottom of the vessel the *Clay* and other earths, with the insoluble animal and vegetable matter. After pouring off the water, dry the sediment, and apply a strong heat, by placing it on the bottom of a pot ignited to redness, and the *animal* and *vegetable matter* will be dissipated in aeriform products.

8.—The remainder lying in the bottom, will be found to consist of *Clay*, *Lime* or *Magnesia*

9.—The next simplest process of in-door analysis, that can be given, is perhaps that practised by the Rev. Mr. Rham Am, and published as a prize essay in the journal of the *English Agricultural Society*. It is applicable to soils only, but is not the less useful on that account, as many conglomerates and rocks in an incipient state of formation may be also readily reduced to powder, and it is often an object to ascertain merely the fact of the presence, or otherwise, in any large quantity of Silica, Alumina and Lime.

10.—A portion of the earth to be analyzed is dried in the sun, or near a fire, until it feels quite dry to the hand. It is then reduced to powder by the fingers, or by rolling it on a deal board with a wooden roller, so as to separate the particles, but not to grind them; any small stones above the size of a pea must be taken out. If these form a considerable part of the soil, their proportion must be ascertained by weight, and their nature and quantity afterwards examined.

11.—Where the stones and pebbles are evidently accidental, they may be overlooked as having little influence on the fertility of the soil. The dry earth cleared from stones should be accurately weighed, and it is convenient to take some determinate quantity of grains, as 1,000, 500, or 250, according to the accuracy of the instruments at hand.

12.—This portion should be put into a shallow earthen or metal vessel, and heated over the fire, or a lamp, for about 10 minutes, stirring it with a chip of dry wood; the heat should not be so great as to discolor the wood. It may then be allowed to cool and be weighed again. The loss of weight indicates the water which remained (or *moisture)* after the soil appeared quite dry. This is the first point to be noted.

13.—The operator should have a set of metallic sieves made so as to fit into one another like the filterers in a coffee biggin, the last fitting into a tin pot, which will hold about a pint of water; a cover being made to fit on the top sieve. Sieve No. 1, the uppermost, is made of a perforated tin plate, the holes about $\frac{1}{20}$th of an inch in diameter. The largest particles or stones are retained by this sieve, and the remainder is successively passed through two or three more sieves, increasing in fineness to the last, which is of the finest wire-cloth, having from 150 to 170 threads to an inch; whatever passes through this, is an impalpable powder.

14.—To render this separation of the earth more complete, washing is resorted to. The coarser sand must be washed with pure water to detach any fine dust adhering to it: what runs through, may be used to wash No. 2, (from the top) in the same manner, and then may pass through No. 3 to the impalpable matter, which passed through all the sieves. A sufficient quantity of water must be used to render the whole of this last nearly fluid. There will be *three* different portions of the washed soil left in the sieves, and a portion of impalpable matter diffused through the water in the lower division of the instrument.

15.—This fine matter is to be well shaken, and suddenly poured into a deep glass vessel, and permitted to settle till the heavier sand subsides; and then the light floating soil is to be cautiously poured off into another vessel.

This washing may be repeated till all the *Sand*, of which the particles are visible to the naked eye, is separated.

16.—In order to detach the "*Humus*," the earth and water decanted out of this last vessel are poured into a glass tube, 18 inches long, the bore of which is less than an inch; one end is stopped with a cork, and the other has a small lip for the convenience of pouring out the contents. In a short time, an earth, chiefly "*Alumina*," will be deposited. What remains suspended in the water, is to be poured off into a similar tube; and this fluid will contain nearly the whole of the *Humus*, which will take some hours to be deposited in the form of a fine brown mud.

17.—To detect *saline* substances in the soil, all the water in which the earths have been diffused and washed is collected, and passed through filtering paper, and then set over the fire in a common sauce-pan. It is boiled away gently until it is reduced to a small portion, which begins to look turbid. The complete evaporation is finished in an evaporating dish as slowly as possible, and the residue is the *soluble matter* contained in the soil.

18.—It will be sufficient to dry and weigh this, as its further analysis would require more skill and chemical knowledge than we suppose in the operator. Salts may be detected by the taste, or by the crystals formed in the evaporation, but unless there is a decided saline taste, the whole may be considered as *Soluble Humus*, and the immediate fertility of the soil depends greatly on the quantity of it.

19.—The next step is to collect, dry, and separately weigh, the *coarse Grit*, the finer *Sand*, the *Earths* in the tubes, the *Humus* on the filter, and the *matters evaporated* in the dish. The total weights of all should nearly equal the gross weight of the dried earth previous to its being washed, but some loss is inevitable.

20.—There remains still to ascertain what quantity, if any, there may be of *Carbonate of Lime* in the form of Sand or of finely-divided earth, mixed with the other earths, and for this purpose each portion, excepting the Humus, is put into a separate cup, and a little Hydrochloric Acid, diluted with four times its weight of water, is poured on it. If there is any effervescence, it shows the presence of Carbonate of Lime; diluted acid is then added gradually, as long as the effervescence is renewed by the addition. When this ceases, and the water continues to have an acid taste, more pure water is added, and each portion separately filtered, dried and weighed. The loss of weight in each, gives the quantities of *Carbonate of Lime* dissolved by the Hydrochloric Acid, and which has passed with the water in the form of Chloride of Lime.

21.—The different weights being now collected, the result of the operations may be set down.

22.—As an example of an analysis (Mr. Rham writes) may be useful to those who desire to try the proposed method, we will add one actually made under very unfavourable circumstances, and without any apparatus.

23.—The only instruments at hand were scales and weights, of tolerable accuracy; three glasses, a foot long and 1½ inches in diameter, belonging to French lamps: a tin coffee-strainer; a piece of fine gauze, and a very fine cambric pocket-handkerchief. A little Muriatic Acid

was obtained at the apothecary's. The soil to be analyzed was taken from a piece of good arable land, on the slope of the Jura Mountain in Switzerland. Its specific gravity was 2.358. Nearly 500 grains of the dry soil were stirred in a pint of water and set by in a basin.

24.—To save time, 500 grains more of the same soil were weighed, after being dried over the fire. It was well pulverized with the fingers, and sifted through the coffee-strainer, then through the gauze, and lastly through the cambric handkerchief. Some portion was left behind at each sifting.

25.—The first two portions were washed in the strainer and the gauze; the residue was *Sand* of two different degrees of fineness, which when dried, weighed, the coarser 24 grains, and the next 20 grains.

26.—The earth and water which had passed through the strainer and the gauze, were now strained through the cambric; and left some very *fine Sand* behind; which dried, weighed and added to what had remained in the cambric when sifted in a dry state, weighed 180 grains.

27.—All that which had gone through the cambric, was mixed with water in a *jug*, and stirred about. The heavier earth subsided, and the lighter was poured into one of the lamp glasses, which had a cork fitted into it and was placed upright. In about two mitnutes, there was a deposit, and the lighter portion was poured into a similar glass, where it was left some time to settle. In this a slower deposition took place, and in about a quarter of an hour, the muddy water was poured off into a third glass. The three glasses were placed upright, and left so till the next day. In the *first* glass was some very fine earth, apparently *Clay;* in the *second* the same, but more muddy; and in the *third*, nothing but thin mud.

28.—The contents of the vessel were left to deposit the sediment in each; this sediment was poured on a plate by taking the cork out of the tube, which was cleaned with a piece of fine linen, which had been carefully dried and weighed. Each plate was examined occasionally, and some of the lighter part that floated on the least agitation was poured from one plate to another, until it was thought that all the *Humus* had been separated.

29.—Most of the water could then be poured off without muddiness; yet it was passed through a dried and weighed paper filter. The earth was slowly dried, by placing the plates on the hearth before a good fire, until they were quite dry, and so hot that they could not be easily held in the hand. The deposit left in the jug (Para. 27)

was poured on a plate, and a little muddy part, which was observed, was poured off with the water on another. This was again transferred, and the finer added to that which was in the second plate.

30.—Collecting now all the separate portions, there were found

Of coarse Sand,..	24	grains.
„ finer Sand, ...	20	„
„ very fine Sand, ...	180	„
Clay deposited in the jug and first plate, and dried,	240	„
Deposit in the second plate, ...	24	„
Ditto on the paper filter, ...	1½	„
Ditto on the linen rag, ...	0½	„
	490	

leaving 10 grains to be accounted for.

31.—Each of the first four portions was put into a separate cup, and Muriatic Acid diluted with water, was poured upon it; an effervescence appeared in all of them, which continued on the addition of diluted acid, and when the contents of the cups were stirred with a piece of tobacco pipe. They were left till the next day, when all effervescence ceased, and the *Calcareous part* seemed entirely dissolved.

32.—Pure water was added to dilute the Muriate of Lime, the clear fluid was then poured off, and the remaining earth was strained through filtering paper, and dried on plates before the fire. The results were that

Of 24 grains coarse Sand,............	20	remained.	Dissolved by Acid	4
20 finer Sand,....................	17	„	„	3
180 very fine Sand,..............	162	„	„	18
240 of the Earth on the first plate,	182½	„	„	57½
				82½

Thus 82½ grains were dissolved, the greater part of which was most probably *Carbonate of Lime,* although there may have also been some Oxide of Iron.

33.—It will be observed, that even in this very simple form of Analysis, the aid of Chemistry cannot be entirely dispensed with, and that Hydrochloric Acid is used to detect the Lime in the soil. Before proceeding with other analysis, therefore, it will be as well to premise a few words on the subject generally of Chemistry.

SECTION II.

PRINCIPLES OF CHEMISTRY AS APPLICABLE TO CHEMICAL ANALYSIS.

1.—The operations of Chemical Analysis are so much better understood, and so simplified and abbreviated by the use of symbols, or Chemical Formulæ, that the comprehension of them is necessary to understand modern treatises on the subject.

2.—The elementary substances which compose the mass of the earth, may be taken as 55, and divided into Non-Metallic (13) and Metallic (42,) or still further sub-divided into 1st, Gases, (3.)—2nd, Non-Metallic Solids, (10.)—3rd, Metallic bases of Earths and Alkalies, (12) —and 4th, Metals (30.)

3.—It will not be necessary to give the whole of these, but only the principal ones, which are—

1*st.* *Gases*—(3)—Oxygen, Hydrogen, Nitrogen.

2*nd.* *Non-Metallic Solids,*—Chlorine, Bromine, Iodine, Fluorine, Silicon, Sulphur, Carbon, Phosphorus.

3*rd.* *Metallic Bases,*—Potassium, Sodium, Magnesium, Calcium, Aluminum, Barium, Strontium.

4*th.* *Metals*—Manganese, Zinc, Iron, Tin, Cadmium, Gold, Arsenic, Cobalt, Chromium, Antimony, Bismuth, Copper, Lead, Mercury, Silver, Platinum, Nickel.

4.—In Chemistry there are two kinds of combination of substances, *viz.*, Chemical combination, and Mixture. A perfect or Chemical combination takes place only when one or more *atoms* of one substance arrange themselves in perfect symmetry by the side of one or more *atoms* of another substance, or of several other substances, so as to form a complete compound *atom*, which afterwards is capable of accumulation like a simple atom.

5.—The *association* of atoms without the formation of compound atoms, is called " mixture," and not " combination."

" Mixture" is seen in the alloys of various Metals, as of Copper and Zinc to form Brass; and also in the mixture of Oxygen with Nitrogen Gases, existing in the atmosphere.

6.—Of the nature of mixture also are the conjunction of Water and Alcohol, or Water and Sulphuric Acid, which will unite in any proportions. Of Water and Salt, also, which will unite up to the point of saturation. Such compounds are of great variety, and are distinguished by their *weak affinities,* as well as by the compounds formed, differing little from their simple constituents, or from each other.

7.—" Combination" is seen in a vast multitude of common substances, of which Water is the most widely extended and the most remarkable. There are three different kinds or stages of combination, and these are: *First.*—" Binary compounds," where one *element* combines with another *element,* as, for instance, Hydrogen and Oxygen to form Water; Oxygen with Sulphur to form Sulphuric Acid; and Sodium with Oxygen to form Soda or Oxide of Sodium.

8.—These combinations of one body with another have the termination in Chemical Phraseology of " ide" or " uret," which terms have the same meaning, and that, it should be remembered is, equal proportions of the combining substances. Thus we have Oxides, Chlorides, Bromides, Iodides or Iodurets, Fluorides, Sulphides or Sulphurets, Carbides or Carburets, and Phosphides or Phosphurets. The Binary compounds of *Oxygen* having Acid properties, are named on a different principle, or according to the quantity of Oxygen they contain. Thus the combination of Sulphur with two parts Oxygen is called Sulphurous and with 3 parts Sulphuric Acid, of Nitrogen with 3 parts of Oxygen, Nitrous Acid, and with 5 parts Nitric Acid. The prefix " Hypo" signifies " less Oxygen" than is in the compound to which it is prefixed. " Hyper" signifies " more."

A " Base" is a compound possessing the power of combining with and neutralizing Acids and a " Neutral Salt" is that which contains as many equivalents of the acid as there are of Oxygen in the Base.

9.—*Secondly.*—Ternary compounds where one " Binary compound" combines with another, or with an " element," as Sulphuric Acid with Soda to make Sulphate of Soda, (Glauber Salts), or Carbonic Acid with Lime to make Carbonate of Lime, or Carbonic Acid with Zinc to make Carbonate of Zinc. Ternary compounds or Salts are named according to the Acid they contain; the termination " ic " being changed to " ate," and " ous" to " ite." Thus from Carbonic Acid and Copper is formed Carbonate of Copper; from Sulphurous Acid and Ammonia Sulphite of Ammonia.

10.—*Thirdly.*—There are combinations of Salts with one another, or double Salts (quaternary compounds) such as Alum, which is a combina-

tion of Sulphate of Alumina with Sulphate of Potash, and is called a Sulphate of Alumina and Potash.*

11.—Atoms of different substances have, however, different *weights.* Thus though *one* atom of Hydrogen and *one* atom of Oxygen combine to form Water, yet 100 parts of Water are found to consist, by *weight,* of 11.1 parts, or grains of Hydrogen, and 88.8 parts of Oxygen, that is by *weight,* they combine in the relative quantities of one to eight. Hence if Hydrogen, the lightest substance known, be taken as a starting point, zero or datum, eight will represent what is called the Chemical "equivalent" of Oxygen.

12.—Let us look at this in another light; A Chemical compound is thus characterized that the *proportions by weight* of its constituents are *invariable.*

That these constituents are present in it in invariable proportions, is regarded as the first and most important law of combination.

13.—Let us take the constituent parts by weight per cent. of some Chemical compounds.

There are found by actual experimental analysis to be in every 100 parts of

Water,	...	Oxygen, Hydrogen,	88.89 11.11	100.
Hydrochloric Acid,	...	Chlorine, Hydrogen,	97.26 2.74	100.
Carburetted Hydrogen,	...	Carbon, Hydrogen,	85.71 14.29	100.
Hydrosulphuric Acid,	...	Sulphur, Hydrogen,	94.1 5.8	100.
Hydriodic Acid,	...	Iodine, Hydrogen,	99.21 0.79	100.

To each part of Hydrogen in the above compounds, there will then be found as follows:

In Water, to	1 of Hydrogen, 8 of	Oxygen,	$\left(\text{or } \frac{88.89}{11.11} = 8\right)$
In Hydrochloric Acid, to ditto, 35.4		Chlorine,	$\left(\text{or } \frac{97.26}{2.74}\right)$
In Carburetted Hydrogen, to ditto, 6		Carbon,	$\left(\text{or } \frac{85.71}{14.29}\right)$
Hydrosulphuric Acid, to ditto, 16		Sulphur,	$\left(\text{or } \frac{94.1}{5.8}\right)$
Hydriodic Acid, to ditto, 126.35		Iodine,	$\left(\text{or } \frac{99.21}{0.79}\right)$

14.—It has been found that the constituents of a simple Chemical

* The term Hydrate will be found frequently used. A Hydrate is a compound in which water is chemically combined with some other substance. Thus, when Water is poured upon Quick Lime, the Water disappears, and the properties of the Lime are modified. The Slaked Lime which results is a Hydrate of Lime.

compound, when they enter into other Chemical compounds, replace each other exactly in the proportion in which they combine; that is, if in a compound of Oxygen, the Oxygen is removed, and Hydrogen is to be substituted for it, then we find always and invariably that 88.89 parts by weight of Oxygen, are replaced by 11.11 parts by weight of Hydrogen; or, which is the same thing, eight parts by weight of Oxygen by 1 of Hydrogen, or by 35.4 of Chlorine (equal to 1 of Hydrogen,) or 6 of Carbon, or 16 Sulphur, &c.

Hence these numbers, 8, 35.4, 6, 16, are called the *combining proportions*, or *Chemical Equivalents* of the substances they represent.

15.—The Formula to express any substance, may, after analysis, be thus determined—

Take, as an example, Acetic Acid, in 100 parts of which there are found to be by weight—

Carbon,	...	47.06	100.00
Hydrogen,	...	5.88	
Oxygen,	...	47.06	

or, which is the same thing, (dividing by 7·84) to 6 of Carbon, $\frac{3}{4}$ of Hydrogen and 6 Oxygen; or again, to 24 of Carbon, 3 Hydrogen and 24 Oxygen. Now the equivalent of Carbon is 6, of Hydrogen 1, and of Oxygen 8, therefore the *Formula* to express Acetic Acid, would be C_4, H_3, O_3, or $24+3+24=51$, its Chemical *equivalent.*

16.—The equivalent numbers of a vast number of substances have been determined by Chemists after actual analysis, and those for any new substances may, in like manner, be determined by observing the proportions by weight in which they combine with another, or with ten others, or with twenty, or with all other bodies. We should thus be able to determine the proportions by weight, in which all these bodies mutually replace each other; that is their Chemical equivalents.

17.—The equivalent of Potash, a combination in equal proportions of Potassium and Oxygen, would be (1 part Potassium$=39.15+1$ part Oxygen$=8)=47.15$, expressed in the Formula $K\ O$.

Of Sulphuric Acid, (1 part Sulphur $16.1+3$ parts Oxygen$=24)=40.1$, Formula $S\ O_3$.

Of Sulphate of Potash, (1 part Potash$=47.15+1$ of Sulphuric Acid $=40.1)=87.25$, Formula $K\ O,\ S\ O_3$.

18.—It is obvious, therefore, that if we can but remember the number of equivalents of each element that enters into the constitution of a compound, we need not burden the memory with analyses expressed in 100 parts, and we can never be at a loss to know the quantity of such compound that will be required, when we wish to employ it for any Chemical purpose.

19.—Thus the student may observe, *that to use the words Nitric Acid, is to express merely a compound substance so called, but to use* the term $N\ O_5$, not only expresses the same equally well, but at the same time serves to recall the fact, that the compound mentioned contains an unusual proportion of Oxygen, *viz.*, 5 parts, to 1 only of Nitrogen; hence its utility in many cases where it is desirable to Oxidize, or afford Oxygen to substances.

20.—A table of symbols and equivalents is appended,† which will explain itself, and for the reason just given, as well as for shortness' sake, the student should endeavour always to use its terms. A brief experience of their great utility will render him unwilling to wade through a complicated and verbose description for information, which he can obtain by a glance at a Formula.

21.—I will now give two processes for *Chemical* Analysis, by which Organic Matter, Lime, Silica and Clay, may be roughly ascertained, as follows:

22.—The first is exceedingly simple;—A convenient quantity, say 100 grains, presenting a fair average of the nature of the specimen, is weighed out, and then pounded and thoroughly dried in the sun or near the fire, to expel all moisture.

23.—Being weighed again, the loss of weight gives the amount of *moisture* in the soil.

24.—It may be then transferred to a crucible, or an iron spoon, and heated to a strong red heat but no more, for a considerable time over the fire. This will burn away all Organic Matter, and being weighed again, the loss from the last operation may be put down as *Organic Matter.*

25.—It should be then transferred to a porcelain dish or saucer, and subjected to the action of dilute Hydrochloric Acid; as much of the Acid being used as is equal to twice the weight of the Earth, and diluted with four times its volume of water. The whole is stirred and allowed to stand for some time, say an hour, with occasional stirring. It is then filtered, and the residue remaining on the filter dried, together with the paper in a covered saucer, near the fire or over a spirit lamp; the dried matter is brushed carefully from the paper* and weighed—the loss is *Lime.*

26.—It is then removed to a test glass, a precipitate glass or a tumbler, and mixed with a quantity of water, with which it is thoroughly washed, and then allowed to settle. After the lapse of about a minute, when the coarser particles have subsided, the supernatant fluid, with the portion of matter still held in suspension, is poured off on to a filter. It

* The end of a quill or feather is a good thing for the purpose; being trimmed till a small part only of the feather is left.

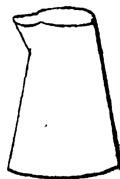
is again treated in a similar manner with the same quantity of water; stirred, allowed to settle, and the liquid poured off on to the filter, and the operation repeated until only *Sand*, and matters incapable of remaining suspended in water for a short time remain.

27.—The suspended matter having been collected on the filter and dried, may be weighed, and deducting the weight of the filter paper, which should be before ascertained, the amount may be considered as *Clay*,

28.—While the other portion in the tumbler, being dried and weighed, will give the Sand or *Silica*.

29.—The second process is the following, and it differs from that of Mr. Rham, chiefly in beginning with the separation of the impalpable portion by washing, and after that, graduating the coarser parts.

30.—A portion of the soil, about 400 or 500 grains, after having the *moisture (A,)* expelled by heat in the usual way, is mixed with water in a Phillips' precipitate glass. The mixture is stirred from time to time till the soil is thoroughly mixed and diffused through the water. The precipitate glass is then filled up with more water, and the mixture is well stirred up. It is then allowed to stand *one* minute, and a syphon (*fig* 2) is introduced. The syphon most useful for this purpose is that of Mitscherlich, which has the shorter leg slightly bent upwards, to prevent its sucking up any portion of the coarser matter that has subsided to the bottom. It is filled by closing the aperture *g* by the forefinger, and sucking out the air at *o*, till the water entering by *c*, rises into the bulb. On removing the forefinger, the water flows. It is allowed to do so till all the water with the finely divided matter held in suspension is drawn off down to the point at which there is danger of disturbing the sediment, or till the air enters by the aperture *c*.



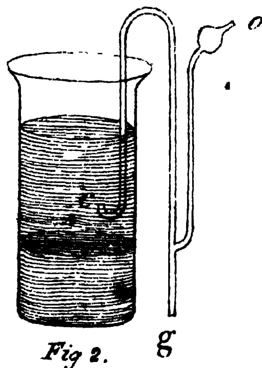
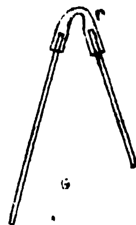


Fig 2.

31.—A common syphon may however be easily made and used thus. Both glass and gutta-percha tubing are furnished with chemical boxes and apparatus, of about ¼ inch diameter. A piece of this glass tubing broken across into two unequal parts, will give the two legs of the

syphon, and a piece of gutta-percha tubing 3 or 4 inches long, will connect them at the top, so as to be quite air-tight. The syphon is then used by inverting it, filling it with water, stopping the two extremities with the fingers, and after again inverting it to its proper position, placing the smaller leg in the fluid to be run off when the water will flow.



32.—The precipitate glass is again filled up with water, and after standing for some time, and being frequently well stirred up, the rough portion is allowed one minute to subside, and the water and suspended matter run off as before; and this process is repeated till no matter capable of remaining suspended for more than one minute is left.

33.—The water and suspended matter may be at once run on to a large weighed filter, but in general it will be found more convenient to run the whole into a large jar or precipitate glass, to be afterwards filtered, dried and estimated. If the soil contains much fine Clay, the impalpable matter may take several days to settle to the bottom completely. It should be allowed to do so. The clear water may then be cautiously poured off, or, what is better, run off by the syphon. The impalpable matter is then well stirred up with the small portion of water left by the syphon above it, and brought on to a previously weighed filter paper. From this filter the water may not at first run quite pure, and if so, the muddy water is returned to the filter after being used to wash out the last portions of impalpable matter in the glass or jar. By the time the whole is got on the filter, the pores of the paper becoming partially filled up with Clay, the water will pass through quite pure.

34.—When all has passed, the filter with its contents is set in a warm place to dry, and afterwards in a dish over a spirit lamp, or in a hot sand-bath till all is thoroughly dried. The sand-bath is merely a vessel or dish of sand, kept at a high temperature by a fire underneath it, and affording an equable warmth, well adapted for evaporating purposes. It is then weighed, and the weight of the dry filter paper which had been previously ascertained, is deducted, and the exact weight of *impalpable matter* noted,—call this *D.*

35.—The clear solution separated from the impalpable matter, contains the *soluble* and *saline portions* of the soil,—call it *B.*

36.—The coarser part of the soil left in the first precipitate glass, out of which the suspended portion was originally run, is now washed out of it, and brought on to a weighed filter paper similar to the last. When the water has passed through, it is dried, weighed, the weight of

the filter paper deducted, and the remainder is the gross weight of the *coarser parts*,—call it *C*.

37.—The amount estimated as *moisture*, *A*, and the *saline solution* of the soluble ingredients of the soil, *B*, may be set aside—and taking the part *C*, let the organic matter be ascertained by ignition to a red heat, in an iron or porcelain spoon or vessel, for some time, till all blackness disappears. The loss of weight in this process, will show the amount of *organic matter*—(*f*).

38.—The coarser parts being now free from very finely divided matter and quite dry, can be easily sifted without sensible loss, and by using sieves of different degrees of fineness, may be separated into as many gradations as the operator thinks necessary. The first may be of wire gauze, 10 threads to the inch; the second also of wire gauze, 40 threads to the inch, and the third (3 being quite sufficient for all practical purposes) of very uniform muslin, 100 threads to the inch. If wire gauze of this degree of fineness can be obtained; it is of course to be used in preference to muslin. Only a single disc should be used at a time, and no attempt made to sift a soil from which the impalpable portion has not been removed. It is not then necessary to wash any of the gradations on the gauze discs.

39.—The dried coarse matter is carefully brushed from the filter paper into sieve No. 1 and sifted; what is retained, is to be regarded as *small stones* (*a*.) All that passed through No. 1 is put into No. 2, and sifted; the portion retained is called *Grit* (*b*.) The portion retained by No. 3 is called *Sand* (*c*), and all that passes through No. 3, is reckoned *fine Sand* (*d*.)

40.—On comparing the relative proportions of impalpable matter, fine Sand, Sand, Grit, and small Stones, we are prepared to form a pretty accurate estimate of the texture of the soil, and to draw the numerous practical inferences that depend on *Texture*.

41.—The nature of these should next be ascertained, and to determine the mineral species that constitute the rough portion of the soil, is a point of considerable importance, for when we know this, we have merely to refer to works on Chemical Mineralogy, to ascertain the substances of which these species are composed, and hence to learn, 1st, what substances are to be looked for in examining the impalpable portion of the soil, when, as frequently happens, that portion has arisen simply from the comminution of minerals of the same kind as the larger parts; and 2nd, what are the inorganic (mineral, &c.) resources of the soil, or what substances it is capable of affording to plants, as decomposition of the larger parts gradually takes place.

42.—By ascertaining the mineral species, we are saved an analysis of the rough part, a thing indeed seldom attempted, but which could not be done without reducing the whole to very fine division of parts. To regard as Silica all the coarse parts that are not acted on by Hydrochloric and Sulphuric Acids, as is often done, is not strictly accurate.

43.—To a Mineralogist the recognition of the mineral species constituting the Grit, Sand, &c., is by no means difficult. First, the more obvious physical characters are ascertained, by examining portions of each of the gradations under a good lens or magnifier, next the hardness may be tried, and lastly, the behaviour of the different species before the blow-pipe, either alone or with the usual fluxes.

44.—Quartz, for instance, will have a vitreous lustre, will scratch glass, and the knife will leave on it a steel grey streak: it will be infusible *per se*, but fusible with Carbonate of Soda into a transparent bead. Mica plates will generally, after heating, present the appearance of golden yellow elastic spangles, capable of being split. Felspar will be softer than Quartz—the knife will scratch it with difficulty; alone it will fuse only on the sharp angles, but with Carbonate of Soda, it will fuse into a vesicular glass, or with Borax into a transparent bead. Calcareous Sand or Grit will be very readily scratched, will effervesce with Acids, will calcine and become highly luminous before the blow-pipe, after which, when moistened on grey Litmus paper, it will communicate a blue stain, &c., &c.

45.—To ascertain the quantity of *Lime* in the coarse soil, it may be operated on with Hydrochloric Acid (*HCl*) as a whole before sifting; but as it is of considerable importance to know the state of division of the calcareous matter, it is better to operate on the small Stones, Grit, Sand, and fine Sand separately, particularly the Sand and fine Sand.

46.—Any convenient quantity (say 50 grains) of the portion to be tried, is treated in the cold with diluted Hydrochloric Acid.—(About twice the weight of the soil in Acid, and diluted with four times its weight of water.) After standing for some hours, and having been well stirred at intervals, the Acid must be ascertained by test paper, (*i. e.*, blue Litmus paper) to be in excess. The solution is now separated from the insoluble residue by filtration through a weighed filter, and the filter is washed entirely free of Acid, dried and weighed. The loss in weight, after subtracting the weight of the filter, indicates the quantity of matter dissolved. If the effervescence on first adding the Acid was considerable, and if the solution is nearly colorless, the loss may be considered as almost entirely *Carbonate of Lime* (*e*).

47.—Let the *impalpable matter, D,* be now taken and treated in a similar way to that pursued with the coarser portion, *viz.*, by ignition, to ascertain organic matter (*g*), which in this state of fine division or decomposition is often, but not quite accurately, called "*Humus*," and afterwards with Hydrochloric Acid to ascertain the *Lime* (*h*.) The remainder will represent *inorganic matter* (*i*).

48.—The process being now concluded, the necessary calculations (from the ascertained percentage in each 50 grains, &c.) are made, and a Tabular Statement is drawn up thus:—

A Water in 100 parts of air-dried soil.

B Soluble matter.

C Coarser parts consisting of

(*a*) Small Stones; naming the mineral species if possible.
(*b*) Grit ditto; ditto ditto.
(*c*) Sand ditto; ditto ditto.
(*d*) Fine Sand; ditto ditto.
(*e*) Calcareous matter in the whole, or in each of the above gradations.
(*f*) Roots and fragments of plants in the whole, or in each of the above gradations.

D Impalpable matter consisting of

(*g*) Organic or Humous matter.
(*h*) Calcareous matter.
(*i*) Inorganic matter.

49.—If the operator be desirous of ascertaining with more correctness the true quantity of Carbonate of Lime present in the soil, the following method may be pursued:

50.—The filtered solution, after treating the soil with Hydrochloric Acid, (HCl) contains, it will be remembered, the Lime in combination with the Chlorine (Cl) of the Acid, which it has seized after liberating with effervescence the Carbonic Acid with which it was previously combined. It is now Chloride or Muriate of Lime in solution.

51.—To the solution Ammonia ($NH_4\ O$) is added in excess, and a precipitate falls consisting chiefly of Oxide of Iron ($Fe\ O$) Alumina ($Al_2\ O_3$) and Phosphoric Acid ($P\ O_5$). This precipitate is separated by filtration, and washed till the water that has passed through ceases to give a white cloudy precipitate when tested with a drop of a solution of Nitrate of Silver ($Ag\ N\ O_5$.) This is in order thoroughly to wash away all trace of the Chlorine of the Acid, and as long as any of it remains, it immediately, on Nitrate of Silver being presented to it,

combines with the Silver, forming Chloride of Silver, a thick white curdy precipitate, which is immediately visible.

52.—The solution may contain Lime (*Ca.*), Magnesia (*Mg.*) and Oxide of Manganese (*Mn. O*), and to separate and estimate the *Lime*, the following steps are taken. To the solution which will be found to contain free Ammonia (by testing for Alkaline re-action with Turmeric paper), Hydrochloric Acid is added to neutralize it, or till it gives but a very feeble Alkaline re-action. Oxalate of Ammonia ($NH_4\ \bar{O}$) is then added as long as it continues to produce milkiness in the solution. The milky precipitate is Oxalate of Lime, and as it cannot be separated from the solution when recently precipitated, on account of its tendency to run through the pores of the filter paper, it is set aside in a warm place to subside.

53.—The best method is to place it on the warm sand-bath at night, and in the morning it will be ready for filtration. Previous to filtration, the solution must be ascertained to be either Alkaline or Neutral. The filtration is of course effected through a weighed filter, and the precipitate is washed with distilled water till no residuum remains, when a drop of the water that has passed through is evaporated to dryness on a slip of platinum foil; the precipitate is then dried.

54.—The Lime may now be estimated, either as Carbonate or as Quick Lime, but the former is more convenient and requires less heat. For this purpose the dried filter paper and precipitate are put into a platinum crucible, and heated to dull redness over the spirit lamp, air being freely admitted to burn off the Carbon, both of the Oxalic Acid and the filter paper. The residue will at first appear of a grey color, but by continuing the heat, this will be got rid of. The heat is then discontinued, and when cold enough, the crucible and its contents are weighed. To make sure, however, that none of the Lime is caustic (that is deprived of its Carbonic Acid), after weighing, the powder in the crucible is moistened with a few drops of a strong solution of Carbonate of Ammonia (to again afford Carbonic Acid) and slowly heated to a very dull red, after which it is again weighed.

55.—A correspondence between the two weights shows, that previous to the first weighing, no Carbonic Acid was lost, but if the second weight exceed the first, it is the second that is taken as the true estimate. After deducting the weight of the crucible and the filter ash, (which must be previously known by burning a similar paper) the remainder is the weight of *Carbonate of Lime* contained in the portion of Grit or Sand operated on.

SECTION III.

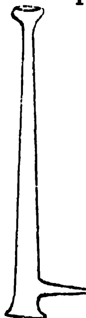
USE OF BLOWPIPE, OR DRY METHOD OF ANALYSIS.

1.—THE method of Analysis last given, contains, it will be observed, two processes of a somewhat advanced and elaborate character, *viz.*: 1*st.*—That for determining the mineralogical character of Grit, Sand, &c., which after examination of the fragments or stones with the lens and the file or penknife, is eventually done by the blowpipe. 2*ndly.*—That, for ascertaining with accuracy by a Chemical Analysis the quantity of Carbonate of Lime present.

2.—Neither of these form essential parts of the Analysis, however; the operator having separated the stones, &c., may, if unable to do it himself, obtain their recognition at other hands, and for all practical purposes the simple form of trial with Hydrochloric Acid, is sufficient to determine the quantity of Lime.

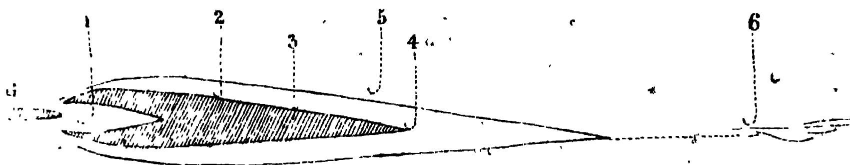
3.—It will be necessary now however, before proceeding to the more intricate and elaborate forms of Chemical Analysis, to devote a few words to the descriptive use of the blowpipe; and of the usual apparatus and re-agents employed in Chemical Analysis. After this I shall, in Section IV., give further examples of Analysis, as of Water, of Soils, and of Mineral Ores; and lastly, in Section V., a detailed process of quantitative and qualitative Analysis, with tables, by the aid of which the student may be able to carry out the Analysis of any substance.

4.—The blowpipe has, by the labours of the German mineralogists, Von Kobel, Plattna, and others, arrived at a pitch of correctness in its results, that must render it a most useful auxiliary to all who would for any reasons avoid the labours with a multifarious apparatus and the precision of manipulation, which is so requisite in the practice of Analytical Chemistry. The kind of blowpipe now generally used is that shown in the margin. The lamp used may be a spirit lamp, or an oil one, or even a candle. A good thick wax candle, with a thick wick, gives as good a flame or perhaps better, than a spirit lamp.



If the blowpipe flame be ragged and irregular, it is a proof that the hole of the blowpipe nozzle is not round or

smooth, and if the flame have a cavity through it, the aperture of the nozzle-pipe is too large.



5.—The action of the blowpipe upon the flame of a spirit lamp, produces a conical flame, which may be divided into distinct parts as follows:—

B being the extremity of the blowpipe.

1 is a small cone of air, formed by the action of the rush of air from the nozzle of the pipe which is highly oxidating.

2 is the outer flame formed by the products of combustion. This is called the "oxidating flame" of the blowpipe, because an assay placed here, has oxygen given to it and is oxidized.

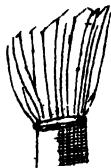
3 is called the "reducing flame," because an assay placed in this portion of the flame is reduced, or deprived of its oxygen.

4 is the point of greatest heat.

5 is a space occupied by hot air, which is very oxidating.

6 is a point beyond the actual visible flame, at and beyond which very oxidating effects are observed.

The direction of the flame should be somewhat downwards, and to effect this properly, the cotton-wick of the spirit lamp or candle should be cut thus, at the top (B being as before the nozzle of the pipe,) and it should, at the same time, be somewhat flattened and spread out, so as to obtain a good volume of flame.



6.—The fragment of mineral used for trial, should be less than half a pea in size, and often a thin splinter is all that is required. It should be supported on Charcoal, which requires to be of a particular kind; firm and close, and not subject to crack up much, as many kinds will do under the intense heat of the flame.

7.—Charcoal is especially necessary when the reduction of the assay needs the presence of carbon; and a platinum forceps (or steel with platinum points) when simple heat is required. Platinum foil for

enveloping the mineral and small platinum cups are also used, but they are expensive. When nothing better is at hand, the mineral Mica may be employed.

8.—Some species require for fusion the aid of fluxes. Those more commonly used are Borax, (Biborate of Soda,) Microcosmic Salt or Salt of Phosphorus, (Phosphate of Soda and Ammonia,) Carbonate of Soda, and Cyanide of Potassium. They are fused to a clear globule, which is readily done, to this the mineral is added; or the flux is powdered, and made up into a ball with the moistened mineral in powder.* In this way some minerals are fused, that cannot be attacked otherwise: nearly all species as they melt undergo certain changes in color, arising from changes in composition. In the absence of all other fluxes, Soap may be used, because on combustion the animal oil and alkali in it become converted into Carbonate of Soda and Charcoal.

9.—Some practice and considerable care is required to watch the small globule of metal surrounded by a quantity of the flux, so much larger than itself when undergoing the heat of the flame. The assay should in the first place be gradually heated. After fusion, in order to obtain the mass or bead, it is necessary to remove it together with the surrounding particles of charcoal into a small mortar, and then to grind it up with water. After standing a minute, pour off the water and again wash, repeating the process of pouring off until the metal remains at the bottom quite free from other matter. If it is brittle, it will be in the state of very small spangles; if malleable, it will have adhered to the mortar or pestle, or a portion of it, whilst the rest may be in large spangles.

10.—The above-mentioned fluxes also are often required in order to obtain the metals from the metallic ores.* On heating a fragment of Copper Pyrites with Borax, a globule of Copper is obtained, and Tin Ore heated with Soda, yields a globule of Tin.

11.—The blowpipe will be found to be in many cases an immediate and useful test. Thus, if we meet with a species of *Clay*, and wish to know whether it be fit or not for the purpose of making porcelain, the blowpipe will decide the question; because for the purpose of making the finer kinds of pottery and porcelain, it is essential to have a clay, which *after burning*, remains perfectly white. Many white clays are

* This is done when the powdered mineral is light, and liable to be blown away by the force of the flame.

to be found, which when burnt, become more or less colored, and many black clays burn perfectly white.

12.—The nature of *Limestone* may also be readily discriminated by it. Limestone fit for making mortar and cement, does not melt by itself, but becomes more or less *white* after being violently heated by the blowpipe flame, and if suffered to cool and then mixed with water, becomes hot, as may be proved by putting a small portion on the hand and letting fall on it a drop of water, when a quick heat will be felt on the skin.

13.—*Silicious* stones never melt alone, but form a glass with Borax and Soda; *Argillaceous* stones, when pure, do not melt, but become white and acquire a flinty hardness; *Fluor Spar* becomes phosphorescent and melts into an opaque white slag; *Zeolites* melt easily, and foam in the flame.

14.—*Aluminous* stones, or the presence of *Alumina* in any notable quantity in a mineral, may also be always detected, provided it be not too much charged with Iron or other coloring matters by the use of the Protonitrate of Cobalt. If a drop be placed on the assay, and it be exposed to the blowpipe flame, it will, after strong ignition, acquire a blue color, more or less vivid and intense according to the purity and abundance of the Alumina which it contains. The test may be applied to the hardest gems or softest clays. When the mineral is a hard stone, it is only necessary to pulverize it well, and to drop on it a minute portion of the test, and then to expose it to the blowpipe flame on platina foil.

15.—Quick Lime, Chalk, Magnesia, Flint, &c., merely acquire, under similar circumstances, a dull grey or black color. Yellow Ochre, which contains Iron, assumes a purple color owing to the red tint of the Iron (under the flame) mixing with the blue color of the Alumina.

16.—The trial of a mineral with the blowpipe may be conducted in the following manner:—

1st. By trying it in an open porcelain dish, or held in a pair of platinum forceps.

To observe, 1st. Whether it fuses.
2nd. Or is volatile.
3rd. Or deflagrates.

2nd. By exposing it to the flame of the lamp in a test-tube temporarily closed at the open extremity.

1st. To observe if it blackens.
2nd. Or is combustible.
3rd. Or is vaporized and condensed into an acid or alkaline liquid.

4th. Or sublimed, and condensed into crystals or powder, and of what color.

3rd. By exposing it to heat in a test-tube open at both ends, held obliquely, (the tube may be three or four inches long, and as large as a quill or larger.)

Again to observe whether—

1st. Acid or Sulphurous vapors are evolved.

2nd. Or sublimates are formed; their color, and if they melt or otherwise; or are chased away on the application of heat. If they become metallic on rubbing; or if they etch the glass, also on rubbing.

3rd. Or if it blackens.

4th. By exposing it to the reducing flame of the blowpipe on Charcoal alone.

1st. To observe if it gives any and what colored incrustation on the surface of the Charcoal, volatilizing at the same time or otherwise.

2nd. If it becomes luminous, remaining at the same time infusible.

3rd. If it fuses and runs into the Charcoal.

4th. If when moistened (after being heated) with Protonitrate of Cobalt and again subjected to the flame, it shows any particular color.

5th.—By mixing it with a Flux and exposing it to the reducing flame either on Charcoal, or on a small bent hook of Platinum wire.

1st. To observe if the Bead into which it melts be brittle or malleable, and of what color; also if it be magnetic.

2nd. To note the incrustations and their color.

17.—Under the first head if it is found to be Fusible, it will denote the probable presence of the fixed Alkalis, Potash or Soda, or of Lead.

2nd. If Volatile, it may be Mercury, Arsenic, Cadmium, Antimony, Zinc, Ammonia, Sulphur or Lead, (partially volatile.)

3rd. If it Deflagrates, that is, crackles and flies to pieces, it may be a Nitrate or Chlorate.

18.—Under the second head—

1st. If it blackens, it would indicate organic matter.

2nd. If combustible, Sulphur.

3rd. If vaporized, Ammonia, Arsenic, Antimony or Mercury may be looked for, and if the vapor condensed into a liquid give an Alkaline re-action with Turmeric paper, it would be probably due to the first of these—Mercury (particularly if mixed with an Alkaline Carbonate,) would sublimate into minute globules visible under a lens.

4th. If there be a yellow sublimate, it may be due to Sulphur, or a white one to Mercury.

The Arsenical crust has a crystalline texture, grey color and shiny appearance. That of Mercury has the same brilliancy, but by a lens is found to consist of minute globules, which may be made to coalesce by the point of a knife.

If Arsenic *as a poison* be the object of search, the sublimate (Arsenious Acid) should be converted into Arsenic Acid by dissolving it in Nitro-Hydrochloric Acid, evaporating to expel the Hydrochloric (which must be *thoroughly* done to prevent a white precipitate of the Chloride of Silver interfering with the results) and then testing with Nitrate of Silver, which with the Arsenic, if present, will form a bright red precipitate of Arseniate of Silver. *This ought never to be omitted.*

19.—Under the third head—

1st. If there be Acid or Sulphurous vapors, they would indicate a Sulphide or Fluoride; a smell of garlic would indicate Arsenic, Acid vapors might be due to Cobalt or Copper.

2nd. A white sublimate might indicate the Ammoniacal Salts, Arsenic, Antimony, Bismuth, Mercury, or Lead, and if this should melt into brown or yellow drops, it would be Bismuth. If it show a metallic appearance on rubbing with the nail or anything hard, Mercury; if it is chased away by the blowpipe flame, Antimony.

3rd. If it blackens, with empyreumatic vapors (as of heated grease) Organic Matter

20.—Under the fourth head—

1st. Lead and Bismuth give yellow incrustations, Zinc and Antimony, white; Tin, none; Cadmium, a yellow or reddish brown.

2nd. If it be infusible but become luminous, then it will be one of the five earths—Alumina, Baryta, Strontia, Lime or Magnesia.

3rd. If it fuses and runs into the Charcoal, some of the Salts of the fixed Alkalies, Potash and Soda.

4th. And if, when moistened with Protonitrate of Cobalt, it show a flesh red color, it would be due to Magnesia; green, to Zinc; blue, to Alumina, Silicic Acid or the Phosphates; and a bluish green to the Binoxide of Tin.

21.—Under the fifth head—

1st. Silica fuses into a transparent glass.

The metals which give brittle beads on fusion, are Bismuth, Antimony.

Malleable beads or lumps are given by Silver, Lead, Copper, Tin, Gold.

Nickel, Cobalt and Iron become Magnetic.

The colors of the various beads to be carefully observed are:—

In the Outer flame.	*In the Inner flame.*
Cobalt, } Blue.	Blue.
Copper, }	Red.
Nickel, Reddish.	Grey.
Iron, Dark-red.	Bottle (dark) green.
Manganese (fused with Carbonate of Soda) Blue-green mass of Manganate of Soda.	Colorless.
Chromium, Green.	Green.

The presence of Sulphur can be detected after fusion by moistening the mass with water, when it will communicate a stain to Silver.

2nd. The incrustations, as before mentioned, of Lead and Bismuth are yellow, and of Antimony and Zinc white: Gold, Silver, Copper, Tin, Iron, Platinum, Nickel and Cobalt, give no incrustation.

22.—From the foregoing we may draw the following *resumé* as regards the metals, and the indications given by them under the blowpipe:—

Iron.—When fused with Borax and Phosphorus Salt, (Phosphate of Soda and Ammonia) gives a dark-red bead in the

outer flame, which becomes lighter on cooling, and in the inner flame, a dark bottle-green, the color of which fades away. It has no incrustation. Iron Ores become magnetic after being sufficiently heated on Charcoal before the blowpipe.

Lead.—With Carbonate of Soda or Cyanide of Potassium, gives a malleable bead and a yellow incrustation.

Copper.—With the same fluxes is reduced to metallic Copper in the mass and in small pieces. In the outer flame with Borax and Phos. Salt, it gives a green bead when hot, which becomes blue on cooling. No incrustation.

Zinc.—Is chiefly known by its white incrustation when fused in the inner flame with fluxes, and by the beautiful green color it assumes when moistened with Protonitrate of Cobalt.

Tin.—Fuses into malleable or ductile grains, and has no incrustation.

Bismuth.—Brittle metallic globules and a yellow incrustation.

Antimony.—Brittle metallic globules and a white incrustation, which is chased away by the flame of the blowpipe.

Manganese.—Fused on Platinum foil with Carbonate of Soda (and addition of a little Nitrate of Potash or Saltpetre) gives a green mass, and fused with Borax and Phos. Salt an Amethyst (reddish) bead. No incrustation.

Arsenic.—Is always known by its odor of garlic and white incrustation, as well as its sublimate of brilliant octahedral crystals.

Cobalt.—With Borax and Phos. Salt, a blue bead. No incrustation.

Chromium.—With ditto ditto, an emerald bead pale in outer, but deeper in inner flame. No incrustation.

Silver.—Melts into metallic malleable Silver, and has no incrustation.

Gold.—Melts in the same manner, and when in solution, may be tested by melting a little Borax on the end of a glass rod, then immersing this in the solution, and then hold- it in the flame of a lamp, when it will show a ruby red color and finally metallic Gold. No incrustation.

Platinum.—Gives no re-action, and cannot be melted by common furnace heat. Minutely divided, it will however dissolve in Nitro-Hydrochloric Acid (that is Aqua Regia or mixed Nitric and Muriatic Acids). Evaporate the solution and dissolve again in water, to which if Iodide of Potassium be added, it will give a dark color, or if

Chlorate of Ammonia, a yellow precipitate of Chloride of platinum.

Mercury.—Is sublimed in a metallic dew on a glass tube, and by scraping this together with a feather, the globules of Mercury become distinctly visible.

23.—In addition to the foregoing, some substances are known by the characteristic color which they impart to the flame of the blowpipe at its extremity chiefly. Thus Soda gives it a strong yellow tinge; Potash a violet color; Lime a crimson red; Strontia a deeper crimson; Baryta and Boracic Acid a light green, and Copper a deep green.

24.—It is of considerable use to acquire the power of maintaining a constant current of air through the blowpipe, at the same time that the drawing of the breath continues regularly, as the operation is then much less fatiguing, and the process of fusing also more quickly performed.*

25.—The mineral should be powdered and sifted so as to use it in a very fine state. A small quantity of the powder lifted on the point of a penknife and placed near the centre of the glass tube in which trial of it is to be made, is sufficient. In observing the process of a metal melting when under the blowpipe, it should be noticed if it appears as a glass, clear or full of bubbles; as enamel, or as a slag.

26.—The Platinum wire should be bent into a hook about a tenth of an inch across and the bent part from $\frac{1}{3}$ to $\frac{1}{2}$ an inch long. As much flux as this will lift, should then be taken upon it and melted in the blowpipe flame; after which a small quantity of the assay can be placed on it and the operation continued. If sufficient flux be not lifted at one dip, more may be taken (after melting the first) by a second, and so on.

27.—When the mass of flux and assay becomes fairly subjected to the heat of the flame, the former melts easily, and froths and bubbles in a large quantity. The operator must not be misled by this to imagine that his metal is already reduced. The operation must be steadily continued, and as it is so, the bubbling mass will gradually become reduced in quantity, and at length the operator will begin to see the small globules of the metal becoming apparent, and rolling about in the fused flux. Some practice and skill are required to keep these together in a convenient mass as much as possible, and not to lose sight of the metallic globules, for, from the small quantity of mineral used, they are

* The Air also in such cases is pure Atmospheric, not deprived of its Oxygen, as it has not passed through the lungs.

of course sometimes exceedingly minute, often scarcely bigger than a pin's head, and even requiring the aid of the lens to distinguish.

28.—The operation of separating these small spangles and particles from the surrounding remnants of flux and charcoal, has been already explained. Spangles indicate that the metal is malleable, but if the metal be left in the form of powder, it is probably not malleable.

29.—To the skilful operator with the blowpipe many other tests are known, and are used, such as the following:—

Boracic Acid is used to detect Phosphoric Acid; Anhydrous Bisulphate of Potash is used to detect Lithia; Boracic Acid, Bromine and Iodine, Gypsum and Fluor Spar are employed as tests for each other, being fusible together into a bead, which is transparent while hot, but opaque when cold.

Tin, in the form of strips of Tin foil, promotes the complete reduction of metallic oxides.

Iron, in the form of very fine wire, is used for detecting Phosphoric Acid.

Silica with Soda is a test for Sulphur, and Sulphuric Acid.

Oxide of Copper is used for detecting Chlorine and Iodine.

For the proper management of these I must refer the reader to Phillips' Mineralogy (last edition), or either of the German authors beforementioned, Von Kobel or Plattna.

30.—The more exact kinds of Chemical Analysis require more extensive apparatus, and the employment of a considerable number of Chemical Salts or Re-agents. Of these I will now give some description, before proceeding to detail the Analyses in which they may require to be employed.

31.—In preparing soils to be operated on, among the first things required are, a pestle and mortar, scales and weights, and washing or precipitate glass jars; together with which glass rods to stir the mixtures are necessary.

32.—The pestle and mortar need not be large, and may be of Wedgewood ware. It is usual to insist generally on the scales and weights used in the operations of Chemistry being very fine and accurate, turning with the 1000th of a grain, kept under a glass case, &c., but for the nature of work to which I suppose the student in India to apply himself, it will, I believe, be found quite sufficient, at least until he have made some advances in Analysis, to use a good pair

of correct apothecaries' scales.* The washing or precipitate jars may be of the shape given in the margin, (*Fig.* 1,) three or four of sizes fitting into each other.

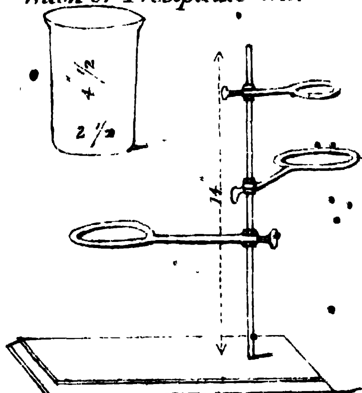


Fig. 2
Filtering and Evaporating Stand

33.—The next things requisite are the apparatus for filtering, which consists of a filter stand with rings to slide attached, three or four glass funnels of different sizes, and filter papers.

34.—The filter stand, if made of Iron throughout with a thick base, will be firm and steady. The sliding rings of about two to three inches diameter move upon the upright Rod, (*see Fig.* 2,) and clamp with a screw at the back. The glass funnels and filter papers are of different sizes. The latter, prepared of a circular shape, 2¾, 4½ and 5½ inches in diameter, and packed in bundles of 100 each, as sold by Messrs Griffin, of Baker Street, are very convenient. They merely require to be folded twice across, and then inserted in the glass funnel. A few drops of plain water will cause the filter paper to settle or adhere to the glass, and both hands can then be employed to pour in the solution to be filtered. This should be done, in order to prevent accidents, by holding a glass rod nearly perpendicularly to the lip of the vessel from which the liquid is poured, and allowing the solution to flow down this on to the paper, which it will do gently and with perfect safety. A too acid solution will corrode through a filter paper, or a too large and heavy one will break through it. The remedy for the former is dilution with water, for the latter the precaution of using a double filter paper. Some glass funnels are grooved at the

* The Table of weights is the following, called "Apothecaries"—

20 Grains	=	1 Scruple	℈
3 Scruples	=	1 Dram	ʒ
8 Drams	=	1 Ounce	℥
12 Ounces	=	1 Pound	℔

Hence 1 Pound is = 5,760 Grains, and a Pint (which is = 1 Gallon or 70,000 Grains divided by 8 or = 8,750 Grains,) is nearly = 1½ ℔ (= 8,640 Grains).

sides to allow the fluid to filter more readily; the Filter paper should always be smaller than the Funnel.

35.—Then for evaporating, there are required half a dozen evaporating porcelain dishes of sizes, packing into each other, and a spirit lamp with Spirits of Wine or a Sand Bath.

36.—The evaporating dishes are very necessary articles, and will be constantly in use. They are placed on the rings of of the filter stand, and the spirit lamp being under them, their height over it is adjusted in accordance with the degree of heat required. But the Sand Bath is a cheaper and more convenient mode of evaporating when not travelling. It consists merely of a Tin or Iron box full of fine Sand, kept hot by being placed over the fire. In this, or on this, the saucers with their contents requiring evaporation are placed; sometimes even a Hot-water Bath similarly managed is used, when only a very gentle and equable heat is required.

37.—When solutions are being filtered, the liquid may be received either in evaporating dishes or in test tubes, for further testing with re-agents. For this purpose will be required therefore one dozen or more glass test tubes, (*see Fig.* 4,) about 6 inches long and ½ to ¾ inches diameter, with a small wooden stand, (*see Fig.* 3,) to hold them, and a small case, similar to a card case, containing Litmus and Turmeric papers. With the tubes should be a tube cleaner, as it is absolutely necessary that they should always be kept clean. In this state they are placed mouth downwards on the pegs of the stand; and when containing solutions under examination put aside for a time, in the holes constructed for them. The Litmus paper (blue) is to test if a solution be acid, which it does by immediately turning red when dipped into it. The Turmeric paper tests the fact of its being Alkaline in like manner by turning brown. As these papers are very sensitive, they will sometimes change color, if only placed near Acids or Alkalies, and should therefore be kept apart.

Fig. 3- Test Tube Stand

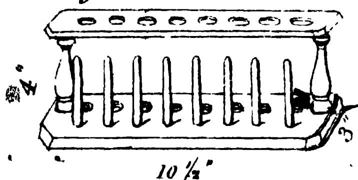
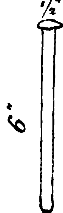
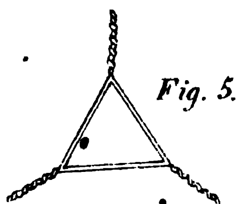


Fig. 4. Test Tube



38.—For fusing metals in the furnace, crucibles are required. These may be Platinum or Porcelain; the former are expensive; small Iron Wire triangles to support them, and also to support watch glasses or very small evaporating dishes, are useful, and also a pair of steel forceps to hold them, remove their covers, &c. If no convenient form of portable furnace be obtained, the fusing may be performed, but of course not so conveniently, over a coke or even a charcoal fire, (two or three parts of coke *mixed* with one of coal and broken into pieces, the size of a walnut, make a good fuel.)


Fig. 5.

39.—For the blowpipe operations before described, are required a blowpipe, platinum wire and foil; some prepared charcoal made from proper wood, a pair of forceps with platinum points, and glass tubes, open and also closed at one end. The nature of these has been before described. The platinum foil is used to evaporate drops of a filtering solution over the spirit lamp, and thus to ascertain by no residue being left on the foil or otherwise whether it be pure or not. The glass tubes are of a thicker kind than the test tubes, which if used, melt and crack under the heat of the blowpipe.

Platinum foil may also be used to envelope such substances as split or decrepitate under the heat of the blowpipe, the Nitrates and Chlorates, for example, and thus prevent their flying about.

40.—Besides the foregoing, glass tubing and India Rubber piping will be found useful to construct Syphons and for other such purposes; such for instance as making a wash bottle, (*see Fig.* 6,) which is used for washing precipitates on a filter perfectly free from any trace of the acid, &c., with which they may have been in solution. By blowing air in through the tube at *a;* as much distilled water as may be required is expelled at *b.*

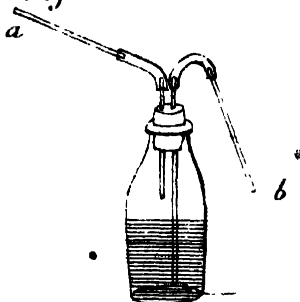
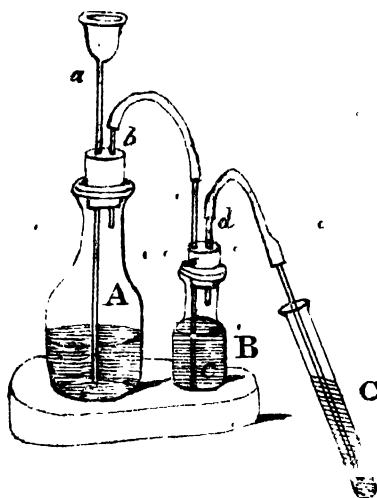


Fig. 6. Wash Bottle

41.—In the last processes of Analysis given, it becomes necessary to use Sulphuretted Hydrogen Gas, which having the strongest smell of rotten eggs, is not by any means pleasant in a house, and is therefore generally employed in the open air. The apparatus for the purpose is figured in the margin (*Fig.* 7,) and may either be made up or obtained ready made. A quantity of Sulphide of Iron is required to be kept; some of this broken up is placed in the bottle *A* and dilute Sulphuric Acid poured on it through the tube *a*. The Sulphuretted Hydrogen Gas ($H\ S$) generated passes up the tube *b*, thence by the aperture *c*, through the water in the bottle *B*, and by the tube *d* it is conveyed into the solution in the test tube *C*, precipitating by its action the sulphides in solution.

Fig 7.

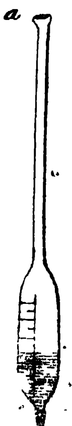


The corks in the necks of the bottles, and every possible aperture must be well luted, to prevent the escape of any Gas, and to ensure the good working of the apparatus. Corks may be covered when necessary with a solution of sealing wax in Alcohol.

The water in the bottle *B* may be preserved, as it becomes impregnated with the Gas and acquires a similar precipitating effect.

42.—A glass tube, with a graduated, elongated and enlarged bulb at the bottom, (*see Fig.* 8,) is useful to take up and transfer to any other vessel a certain amount, and no more, of water or any Acid. The tube is immersed in the bottle containing the liquid, the upper end being left open till the required amount of liquid has risen into it; by merely then closing the upper aperture *a* with the finger, the liquid is prevented from falling back into the bottle when the tube is lifted out, and by again removing the finger when it is held over the vessel to which the transfer is to be made, the liquid is allowed to fall into it.

Fig. 8.



43.—All the apparatus mentioned, with the exception of *Platinum* capsules, and evaporating dishes, which are expensive, may be procured in a compact box measuring 1′ 9½″ × 12″ × 10½″ together with a tray fitting into the same and containing 35 bottles, glass stoppered, of Acids and Re-agents, such as will be described, for about £6 or £7, from Messrs. Simpson and Co., No. 1, Kennington Road, or from Messrs. Griffin, 10, Finsbury Square, London.

44.—The foregoing are some of the most necessary and useful apparatus for Chemical Analysis. The operator may, however, make up many things for himself with the aid of glass bottles and tubing, Cork and Gutta Percha or Caoutchouc. Sheet Caoutchouc will effect many joinings of glass tubes if cut clean and joined *immediately* while the edges of the cut are fresh.

Herein lies one great difference between modern chemical operators and the alchemists of old. Where they had furnaces, and complicated iron vessels on a large scale, which obliged them to work in a spacious and separate laboratory, the modern Chemist, by the use of Gas, Spirits of Wine, Platinum, Cork, Glass and Gutta Percha, or Caoutchouc, is enabled to work almost in his own drawing-room at many operations of Analysis.

45.—Liebig, in his admirable letters on Chemistry, from which I have borrowed largely, and which affords a delightful treat to all, but to the chemical reader especially, writes thus on the subject:

46.—"Without Platinum it would be impossible in many cases to make the analysis of a mineral. The mineral must be dissolved, and it must be first rendered soluble or prepared for solution. Now vessels of Glass, of Porcelain, and of all non-metallic substances are destroyed by the means we employ for that purpose. Crucibles of Gold and Silver melt at high temperatures. But Platinum is cheaper than Gold, harder and more durable than Silver, infusible at all temperatures of our furnaces, and is left in tact by Acids and Alkaline Carbonates; Platinum unites all the valuable properties of Gold and Porcelain, resisting the action of heat and of almost all chemical agents.

47.—"Glass, transparent, hard, colorless, unchanged by Acids, and most other liquids, and at certain temperatures more plastic and flexible than Wax, it takes, in the hands of the Chemist, and in the flame of a proper lamp, the form and shape of every piece of apparatus required for his experiments."

48.—*Cork.* "What precious properties are combined in cork! How little can any but Chemists appreciate its value and recognize its good

qualities! We might cudgel our brains in vain, in the hope of replacing Cork, as the ordinary means of closing bottles, by any other substance whatever. Let us imagine a soft highly-elastic mass, which nature herself has impregnated with a matter of properties resembling wax, tallow and resin, yet dissimilar to all these, and termed *suberin.*

"This renders it perfectly impermeable to fluids, and in a great measure even to gases. By means of Cork, we connect wide apertures with narrow ones; with Cork and Caoutchouc we connect our vessels and tubes of glass, and construct the most complicated apparatus with the aid of the brass founder, and the mechanist of screws and stop cocks. Thus the implements of the Chemist are cheaply and easily procured, immediately adapted to any purpose, and readily repaired or altered."

49.—"For a laboratory a light, warm, comfortable room, instead of a damp, cold vault, where beautifully constructed lamps supply the place of furnaces, and the pure and odorless flame of Gas, or of Spirits of Wine, supersedes Coal or other fuel, and gives us all the fire we need.

"To these simple means must be added the balance, and then we possess every thing which is required for the most extensive researches."

50.—The principal *Acids* and *Re-agents* likely to be required, may be enumerated as follows:

Acids,......	Mineral or Inorganic, ...	1, Sulphuric; 2, Nitric; 3, Hydrochloric;
	Vegetable or Organic, ...	4, Acetic; 5, Tartaric; 6, Oxalic;*
Volatile Alkali, ...	Ammonia or the *Volatile* Alkali, ...	7, Ammonia; 8, Oxalate of; 9, Carbonate; 10, Sulphide of Ammonium; 11, Chloride of Ammonium;
Fixed Alkalis, ...	12 Potash or the *Vegetable* Alkali,	13, also the Nitrate; 14, Chromate; 15, Sulphate; 16, Ferro-Cyanide of Potassium; 17, and Ferri-Cyanide of Potassium; 18, Cyanide of Potassium; 19, Carbonate of Potash;
	Soda or the *Mineral* Alkali,	20, Carbonate of; 21, Phosphate; 22, Biborate; 23, Phosphate of Soda and Ammonia.

* Another Vegetable Acid, Gallic Acid, was at one time much used, chiefly as a test for Iron, but is not so now in the presence of other tests, as the Ferro-Cyanide of Potassium, or Prussiate of Potash, &c,

Besides the above—

24, Sulphate of Magnesia; 25, Nitrate of Silver; 26, Protonitrate of Cobalt; 27, Nitrate of Lead; 28, Sulphate of Copper; 29, Chloride of Barium; 30, Protochloride of Tin; 31, Perchloride of Gold; 32, Per or Bichloride of Platinum; 33, Perchloride of Iron; 34, Perchloride of Mercury; 35, Sulphide of Iron; 36, Protosulphate of Iron; 37, Acetate of Soda; 38, Protonitrate of Mercury; 39, Sulphate of Lime; 40, Nitrate of Ammonia; 41, Lime Water; 42, Alcohol; 43, Chloride of Calcium.

51.—SULPHURIC ACID.—Oil of Vitriol (SO_3). Is found in the inorganic kingdom in the waters of some Volcanic regions, evidently produced by the combustion of Sulphur. In the organic kingdom, the Sulphates of Lime, Potash and Soda have also been found in plants. When mixed with water, Sulphuric Acid evolves heat; Free Sulphuric Acid, or the soluble Sulphates, are recognized by a solution of any of the Barytic Salts as (Chloride of Barium) $BaOCl$ which throws down a heavy white precipitate, (Sulphate of Barytes) BaO, SO_3 insoluble in Acids or Alkalies. If this precipitate or any insoluble Sulphate be ignited with Charcoal, it is decomposed, and converted into a Sulphuret, (or, which is the same thing, a Sulphide or equal proportions base and acid), which on the addition of Hydrochloric Acid (HCl) evolves Hydrosulphuric Acid (HS or Sulphuretted Hydrogen), known by its odor (rotten eggs), and by its blackening paper moistened with Acetate of Lead ($Pb. \bar{A}$) or any soluble Salt of Lead. If Sulphuric Acid (SO_3) be heated with organic matter, Sulphurous Acid (SO_2) is given out; this may be known by its odor, and by its occasioning the formation of the blue Iodide of Starch, when mixed with Iodic Acid and Starch.

When some Sulphurets, as for example Iron Pyrites ($Fe\ S_2$), are heated in the closed tube, part of the Sulphur is volatilized. If a mineral containing Sulphuric Acid, or Sulphur be fused on Charcoal in powder with two parts Soda (NaO) and one of Borax, and then placed in a drop of water on a bright surface of Silver, the Silver will turn brown or black.

To determine whether Sulphur exists in a compound as a Sulphide or as a Sulphate, the powdered mineral may be boiled with Caustic Potash and water, and then filtered. In this solution, if a bright piece of Silver (as a rupee) be placed, it will, in the case of a Sulphide or Sulphuret, be blackenened over the surface, but not otherwise.

The suffocating fumes which arise from burning Sulphur are Sulphurous Acid (SO_2). This acid is used to bleach sponge; Sulphuric

Acid is also much used for bleaching. Mineral Sulphurets on Charcoal, or in the closed tube, evolve Sulphurous Acid also.

Sulphurous Acid is prepared by acting upon Copper or Charcoal with Sulphuric Acid. For this purpose small pieces of Charcoal are introduced into a flask with from six to eight times their weight of Sulphuric Acid and a moderate heat applied. The evolved Gas must be conducted into cold water until it is no longer absorbed. On account of the great tendency which this Re-agent has to absorb more Oxygen, and become converted into Sulphuric Acid, it must be preserved in well-stoppered bottles.

Sulphuric Acid is frequently impure by the presence of Lead (employed in its manufacture). This may be detected by adding water, when the white insoluble Sulphate ($Pb\ SO_3$) is precipitated; or by adding Hydrosulphuric Acid (HS) to the dilute acid when a very slight change of color indicates the formation of the black Sulphuret of Lead ($Pb\ S$).

Dilute Sulphuric Acid poured on the Sulphide of Iron produces the Gas called Sulphuretted Hydrogen (HS).

Sulphuric Acid and the soluble Sulphates precipitate Strontia and Lime. The former completely, but the precipitate will not appear immediately, unless the solution be very concentrated.

The latter only partially and in concentrated and cool solutions, and the precipitate re-dissolves in a larger amount of water. Hence Chalk, Carbonate of Lime ($CaO\ CO_2$) is sometimes used to detect Sulphuric Acid.

Sulphuric Acid is used to discover the acid with which any base may be combined, as when poured on it and heat is applied, it expels the Nitric, Hydrochloric, Acetic and Fluoric Acids. These may be discovered by their appropriate tests, *viz.*, the reddish fumes of Nitrous Oxide and the Salt deflagrating if a Nitrate; if Hydrochloric, by Nitrate of Silver and the formation of white fumes with Ammonia. The pungent vapor of vinegar if Acetic, and etching glass if Fluoric.

52.—NITRIC ACID—(2) or Aquafortis—(NO_5).

In the inorganic kingdom the Nitrates of Potash (Saltpetre) ($KO\ NO_5$) Soda, Lime, and Magnesia are found on the surface of the earth in various parts of the world.

In the Organic, the Nitrates of Lime and of Potash have been found in plants.

When Nitric Acid is mixed with water, heat is evolved. It evolves white fumes, and must therefore be kept in a tightly closed

bottle; light also affects it; it stains the skin yellow. It parts readily with its Oxygen, oxidizing all the metals except Gold and Platinum, and some of the rarer ones, becoming itself converted into Nitric Oxide (or the Binoxide) ($N\,O_2$) which, in contact with the air, is changed into red fumes of Nitrous Acid ($N\,O_4$.)

All the Oxides of Metals generally met with, dissolve in it except the Binoxide of Tin ($St\ O_2$) and Oxide of Antimony ($An\ O$.) Gold and Platinum remain unaltered by it, hence it is generally used as a solvent for alloys of the precious metals, as, if complete solution takes place, Gold, Platinum, Tin and Antimony must be absent. If a white insoluble sublimate separates, Tin and Antimony are indicated, and if a metallic residue, Gold and Platinum.

If Hydrochloric (Muriatic) Acid, ($H\ Cl$) be added to Nitric Acid, four parts of the former to one of the latter, the powerful solvent called Aqua Regia is produced, which has the power of dissolving leaf Gold and also Platinum in small division of parts. The presence of Gold in solution may be tested by the Protochloride of Tin ($St+H\ Cl$) or the Protochloride of Iron, which gives a purple or dark color known as the purple of Cassius.

Dilute Nitric Acid will detect Steel from Iron. A drop on the former will cause a black stain after remaining a few minutes, converting the Carbon of the Steel into Charcoal. On Iron it merely leaves a grey stain, but must be used so dilute as feebly to act only on the blade of a common penknife. If a rough article, it should be first cleaned with a file or emery paper, and then the Acid applied very dilute.

Nitric Acid is used to detect Starch in vegetable substances. If the substance be digested for some days in dilute Nitric Acid, and Alcohol be then added, Starch will be thrown down.

Nitric Acid may be thus detected: evaporate a portion of the solution supposed to contain Nitric Acid to dryness; add Sulphuric Acid and Solution of Sulphate of Iron; when the solution assumes a brown tint, more or less deep according to the quantity of Nitric Oxide evolved.

Nitric Acid liberates Iodine from its Hydrogen and metallic compounds, Nitric Oxide being given off. The liberated Iodine communicates a brownish yellow tint to the solution, and if it is concentrated a portion of the Iodine separates as a black precipitate. When solid Iodides are heated with Nitric Acid, the Iodine sublimes in the form of violet colored vapors, which condense upon the colder parts of the vessel as a blackish sublimate.

The Nitrates deflagrate when heated by the blowpipe, or thrown on a red hot Cinder or Charcoal, and heated in the closed tube, they yield Nitrous Acid, which is known by its color and smell. Nitric Acid is generally used dilute, one to five of water.

53.—HYDROCHLORIC ACID—(Muriatic,) (Spirit of Salt.)—(*H Cl.*)

In the Inorganic kingdom it is found as one of the gaseous products of Volcanoes. Combined with Ammonia, it is found in Volcanic regions.

In the Organic, it is an essential constituent of the Gastric juice.

Chlorine Gas (Deriv. from χλωρος, green,) is obtained by the action of four parts of Hydrochloric Acid on one part of Peroxide of Manganese, a gentle heat being applied. A solution of the Gas may be prepared by passing it into cold water, but it must be excluded from light and kept in well-stoppered bottles.

It fumes in the air, from its affinity for aqueous vapor, which it condenses, hence the fumes; and also more strongly when in contact with the vapor of Ammonia, whence the presence of the latter is detected, or *vice versa* that of the former, by using a glass rod moistened with one and held over the vessel supposed to contain the other.

Its presence is readily detected in solution by the Nitrate of Silver, which causes with it a precipitate of the Chloride of Silver. This being very white and clotty or curdy, is immediately perceptible; the precipitate also blackens by exposure, and is insoluble in Nitric Acid, but soluble in Ammonia.

Chlorine may be detected by being heated with Chromate of Potash and concentrated Sulphuric Acid, a brown gas is disengaged which condenses into a blood red liquid (Chromate of Chloride of Chromium). On adding Ammonia in excess, the color changes to yellow, owing to the formation of neutral Chromate of Ammonia; on the addition of an Acid, the yellow changes to a reddish yellow color, owing to the formation of an Acid Chromate.

Hydrochloric Acid precipitates the Oxides of Silver, Mercury and Lead, as Chlorides. The Chloride of Silver (*Ag Cl*), insoluble in Water, is soluble in Ammonia, but can be re-precipitated by any Acid, as this would destroy the solvent. Chloride of Lead (*Pb Cl*) is slightly soluble, but not in Ammonia. Chloride (Protochloride) of Mercury (or Calomel) is insoluble in water, and changes in color from white to black with Ammonia.

In combination with Ammonium or Potassium (Chloride of Potassium) it is used as a test for Platinum, producing a yellow crystalline

precipitate, the formation of which is promoted by free Acid. The Chlorates when heated evolve Oxygen and are converted into Chlorides.

By itself it cannot dissolve Gold or Platinum, but mixed with Nitric Acid (making Aqua Regia) it does do so.

It is occasionally impure with Iron or Sulphuric Acid. The former may be detected by saturating the Acid with Carbonate of Soda (*i. e.*, making it neutral) and then adding the Ferro-Cyanide of Potassium, when a blue tint will be produced, or it may be supersaturated with Ammonia or its Carbonate, when a red tint, that of the Peroxide or Sesquioxide of Iron, will be shown.

Chloride of Barium will detect Sulphuric Acid, but the Hydrochloric Acid should be first diluted with five or six times its volume of water.

Hydrochloric Acid is used dilute, one to four of water.

54.—ACETIC ACID—(4) ($HO\ C_4\ H_3\ O_3$) = ($Ho\ \bar{A}$) or $\bar{A}$.

Is met with free, or combined with Potash, Lime, or Ammonia in the juices of many plants; Acetates of Potash and Lime have been found in the sap of the elm, and Acetate of Ammonia in the fruit of the Areca Catechu.

The Vinous fermentation produces Alcohol, and Alcohol by oxidation is converted into Acetic Acid.

It fumes like Hydrochloric Acid with Ammonia, and produces no precipitate with Lime, Baryta or Nitrate of Silver. With Potash it forms a very deliquescent Salt. Alum is soluble in it. It crystallizes in rhomboidal plates.

Acetic Acid of considerable strength may be prepared by saturating perfectly dry Charcoal with common vinegar and distilling; the water comes over first, and as the heat increases, is followed by the Acid. Strong Acetic Acid is also obtained by exposing vinegar to a freezing temperature, when the water congeals while the Acid remains liquid, and may be strained off.

It may be impure with the Acids, or with Copper, Tin, Lead, &c. Sulphuric Acid, if present, will be detected by Chloride of Barium, Muriatic Acid by Nitrate of Silver, Nitric Acid by introducing a piece of Silver, when, the Nitrate of Silver being formed, its presence would be detected by Hydrochloric Acid, as before. Lead, Copper or Tin would be recognized by the precipitate produced by Hydrosulphuric Acid, (HS), which throws down the Sulphates of these metals respectively white, blue and white colored, or by Ammonia. Lead would also be

detected by the Iodide of Potassium, which would throw down a yellow precipitate of Iodide of Lead.

All the Salts of Acetic Acid are soluble; those of Mercury and Silver the least so.

The Persalts of Iron impart to solutions of the Acetates a blood red color.

Several Acids, when distilled at a high temperature, undergo decomposition, and new Acids are formed.

Their names remain the same, or have the word "pyro" prefixed, as Pyrocitric Acid, Pyrogallic Acid; Pyroligneous Acid (or thus concentrated Acetic Acid,) is obtained by destructive distillation from wood for chemical purposes.

Acetic Acid is generally used dilute, one to four of water, and is employed to re-dissolve precipitates, and acidify solutions, and is useful in the separation of Phosphoric Acid.

55.—TARTARIC ACID—($2\ HO,\ C_8\ H_4\ O_{10}$ or $2\ HO.\ \overline{T}$.)—

Spoils when in solution, and is therefore generally kept in crystals. It is termed a fixed organic Acid, as it cannot be distilled or volatilized without decomposition.

Tartaric Acid is peculiar to the vegetable kingdom. In the free state it exists in Tamarinds, Grapes, the Pine Apple and Pepper. It is found in combination with a base, as in the form of Bitartrate of Potash in Tamarinds, Grapes, Mulberries, &c.

It is the sour principle of Grapes. On the side of the vessels containing fermenting Grapes (for wine) crystals of this acid, called Argal or Tartar, combined with Potash, are formed, and these when purified are Cream of Tartar.

Cold water dissolves crystallized Tartaric Acid; boiling water takes up twice its own weight of the Acid. Alcohol sparingly dissolves it. Heated with either Nitric Acid (NO_5), or Potash(KO), it yields Oxalic Acid, ($\overline{O}$) By the action of Sulphuric Acid, (SO_3) on it, Acetic Acid ($\overline{A}$) is formed.

With lime water it yields a white precipitate (Tartrate of Lime) soluble by either excess of Acid or the addition of a little Sal Ammoniac, (Muriate of Ammonia,) but insoluble in water. Dropped into a solution of Sulphate of Lime it furnishes no precipitate. Heated with a solution of Chloride of Platinum, Tartrate of Potash occasions a black precipitate, metallic Platinum. With Nitrate of Silver, Tartrate of Potash furnishes a white precipitate (Tartrate of Silver,) which when heated, does not deflagrate, but becomes brown, froths up, evolves white

fumes, and leaves pure Silver. Acetate of Lead throws down a precipitate from a solution of the Salt, which if the Salt be pure, is soluble in Nitric Acid, but if insoluble, it would indicate the presence of Sulphuric Acid or a Sulphate.

Tartaric Acid throws down from concentrated Neutral, or Alkaline Solutions of Ammonia or Potash, a white crystalline precipitate of Bitartrate of Ammonia, (NH_4 *O, HO,* $\overline{T}$), and Bitartrate of Potash (*KO, HO,* $\overline{T}$), which is soluble in water, the free Alkalies and the Mineral Acids.

It produces no precipitate in solutions of Soda, as the Bitartrate of Soda is soluble.

Chloride of Barium produces in solutions of the Tartrates a white precipitate of Tartrate of Baryta, which is soluble in solutions containing Ammoniacal Salts. Chloride of Calcium, (Muriate of Lime) precipitates from solutions of the Tartrates a white precipitate of Tartrate of Lime, insoluble in water, but soluble in Acetic Acid, the Mineral Acids, and solutions containing Ammoniacal Salts. It is distinguished from Phosphate of Lime and Borate of Lime by dissolving in a cold solution of Caustic Potash, from which solution it is precipitated on boiling and again re-dissolved as the liquid cools.

Tartaric Acid is used in the proportion of one to two of water, and chiefly for the determination of Potash, Ammonia, Tin and Antimony (as Antimony dissolves, but Tin does not, in a hot concentrated solution of it); also to acidify solutions to render them neutral.

56.—OXALIC ACID—(*HO,* C_2 O_3 or *HO,* $\overline{O}$)—

Is usually placed among the Organic Acids, but as its Salts upon ignition leave no Carbonaceous residue, it is sometimes included in the list of inorganic Acids. It crystallizes in 4-sided prisms, is the acidulous principle of the Wood Sorrel (*Oxalis Acetosella*), and is, as is well-known, highly poisonous. It also exists uncombined in the liquor which exudes from the pea, *Cicer Arietinum,* and may be procured from the geranium acidum.

It may be obtained readily and economically from Nitric Acid and Sugar, crystallizing in prismatic and needle-shaped crystals. Let 6 oz. Nitric Acid and 1 oz. Sugar be distilled to a syrup and allowed to crystallize. The crystals must then be dissolved in water, re-crystallized, and dried on blotting paper.

Oxalic Acid readily dissolves Alumina, and the solution gives, on evaporation, a yellowish transparent mass, sweet and a little astringent to the taste, deliquescent and reddening Litmus paper. This Salt

swells up in the fire, loses its acid and leaves the Alumina a little colored.

Its usual form is in combination with Potash or Ammonia. In the latter it is very useful as a test for Lime, which it detects in even very dilute solutions, forming with it a decided white precipitate of Oxalate of Lime, which is insoluble in Acetic Acid ($\bar{A}$.)

The Oxalate of Potash, under the name of "essential Salt of Lemons," is employed to remove Ink-stains and Iron-moulds from linen.

All the Oxalates are decomposed at a red heat into Carbonic Acid (CO_2) and Carbonic Oxide (CO.) If the base with which the Acid is combined be an Alkali or an Alkaline Earth, it is left as a Carbonate; the other bases are left either in an oxidized or metallic state, according to their greater or less affinity for Oxygen.

Oxalic Acid is used to precipitate both Baryta and Strontia from their solutions. This it does better with the aid of Ammonia, and more readily the latter than the former.

One part by weight of the Acid in 20 parts by measure of water is the common mixture for use.

57.—AMMONIA.—(NH_3)

When Ammonia, a gas, which consists of Nitrogen and Hydrogen, is dissolved in water, it unites with one atom (HO) forming $NH_4\ O$, and this is the usual form in which we have it.

Free and in combination it exists in both kingdoms of Nature. In the Inorganic, the Muriate and Sulphate are found in the neighbourhood of valcanoes. The former also in Sea Water and in some Mineral waters. Ammonia exists in many of the native Oxides of Iron, and in some Chalybeate waters.

In the Organic kingdom it is found in green vegetables, in small quantity only; it is developed as Carbonate of Ammonia during the decomposition (spontaneous or artificial) of most vegetable substances which contain Nitrogen, as Gluten. It is one of the products of the putrefaction of animal matters, and is found in urine, in dung, and in rain water.

Ammonia is readily recognized by its peculiar odor, by its action on turmeric test paper, which it reddens, or reddened Litmus paper, which it turns blue, and by its forming white fumes, as before stated, with Hydrochloric Acid. If any stronger base, as Lime, Potash, or Soda be added to a solution containing it, it will be liberated, and may be recognized as above. Its presence in rain water may thus be detected.

If Sulphuric or Hydrochloric Acid be added to rain water in small quantity and evaporated nearly to dryness, and then a little powdered Lime added, the Ammonia which was in combination with the Acid will be separated, and recognized by its pungent odor.

Ammonia and its Salts impart to the blowpipe flame no characteristic color as Potash and Soda, the other Alkalies do, *viz.*, the former violet, the latter yellow.

Perchloride (Bichloride) of Platinum ($Pt\ Cl_2$) produces in neutral and Acid solutions of Ammonia, a yellow crystalline precipitate, which is a double Salt of Chloride of Ammonium and Chloride of Platinum ($NH_4\ Cl,\ Pt\ Cl_2$.) This precipitate is not readily observable at first, but is apparent on standing.

Ammonia precipitates even in the presence of its Salts, the Oxides of Alumina ($Al_2\ O_3$) the Oxide of Chromium ($Cr_2\ O_3$) and the Peroxide of Iron ($Fe_2\ O_3$) as Hydrates, the last of a red brown color. The precipitates are insoluble in an excess of the re-agent.

If its Salts be not present, it also precipitates the Protoxide of Iron ($Fe\ O$) and the Oxide of Manganese ($Mn\ O$) as Hydrates, insoluble in excess of the re-agent, but not in the presence of its Salts.

Zinc it precipitates as Hydrate ($ZnO,\ HO$) Nickel also as Hydrate of a green color ($NiO,\ HO$), and Cobalt as a light blue precipitate, all three soluble in excess of the re-agent.

Lead and Bismuth are precipitated by it as Hydrates insoluble in excess of the re-agent, and a similarly insoluble white precipitate of Mercury is formed from solutions of the Peroxide of Mercury. The precipitates of Cadmium and Copper (the latter of a fine blue color) are soluble in excess of the re-agent.

Ammonia communicates a deep blue color to the Salts of Copper. The same effect is produced with Nickel, but in order to discriminate, saturate in excess with Sulphuric or Nitric Acid, and then immerse a slip of Zinc. Copper will be precipitated on this, but not Nickel.

A beautiful green color is frequently given to pickles by boiling them with half pence, or allowing them to stand in Copper vessels for some time. The Acetate of Copper, or Verdigris (a poison), is thus formed from the Vinegar and Copper. The minutest quantity of Copper may, however, be detected by Ammonia diluted with an equal bulk of water poured over the chopped pickles, as it directly assumes a blue color.

Ammonia is useful as distinguishing the Salts of Lime and Magnesia. The former it does not precipitate, at least when present alone,

but Magnesia it precipitates partially, and when Alumina is present with it, completely.

If pure, when a portion of the liquid Ammonia has been neutralized by pure Nitric Acid, it ought not to cause a precipitate by the addition of the Nitrate of Silver, of Oxalic Acid, or of Carbonate of Ammonia; for the first would indicate the presence of Hydrochloric Acid; the second, of Lime; and the third, of Lime or other earthy matter.

Ammonia is very useful in all Analysis, as it decomposes most of the metallic Salts, excepting those of the earths Potash, Soda, Lithia, Lime, Baryta, Strontia.

It is generally used dilute with four parts of water.

58.—OXALATE OF AMMONIA.—($NH_4\overline{O}$ C_2 O_3)—

Is found in considerable quantity in Guano and other manures. It is chiefly used as a test for Lime. The precipitate obtained, Oxalate of Lime, is insoluble in Acetic Acid.

By ignition, this Salt, like all the other Oxalates, is decomposed, a Carbonate being left.

Other tests used for Lime are, the Acetate and Nitrate of Lead, and a solution of Soap in Alcohol. Alcohol being composed of Carbon, Hydrogen and Oxygen (C_4 H_6 O_2) the Carbonic Acid combines with the Lime, producing a white precipitate of Carbonate of Lime, which is insoluble in Alcohol, and is consequently precipitated.

It is used generally in the proportion of one by weight of the Salt to 20 by measure of water.

59.—CARBONATE OF AMMONIA.—($NH_4\overline{O}$, CO_2)—

Called also Sal Volatile, is formed during the decomposition or destructive distillation of those substances, such as vegetable matters which contain Nitrogen (*N*).

The Sesquicarbonate is Smelling Salts or Hartshorn, and is formed differently, *viz.*, from Muriate of Ammonia and Carbonate of *Lime.*

Carbonate of Ammonia is very useful in Analysis. It precipitates Baryta, Strontia and Lime as Carbonates, but Magnesia only partly, and the presence of Salts of Ammonia prevents the precipitation altogether.

It precipitates Bismuth, Cadmium and Lead from their neutral solutions as Carbonates, the precipitates being insoluble in an excess of the re-agent. Mercury it in like manner precipitates when in solution, as Peroxide.

Copper, it precipitates from neutral solution with a beautiful greenish blue color. This precipitate is soluble in an excess of the re-agent.

It precipitates Antimony as the Oxide ($Sb\ O_3$) and Tin from its Persalts, in solution as the Hydrate. Both precipitates being soluble in the fixed Alkalies, but not in Ammonia.

It precipitates Alumina ($Al_2\ O_3$), Chromium, ($Cr_2\ O_3$) and Peroxide of Iron, ($Fe_2\ O_3$) from solution as Hydrates, with evolution of Carbonic Acid: Protoxide of Iron ($Fe\ O$) as the Proto-Carbonate (FeO, CO_2) which is soluble in Chloride of Ammonium, and Manganese, also as the white Proto-Carbonate ($MnO,\ CO_2$) insoluble in an excess of the re-agent.

Zinc, Nickel and Cobalt it precipitates, of a white, yellow and pink color respectively; the precipitates being readily soluble in an excess of the re-agent.

Carbonate of Ammonia is used one part by weight of the Salt to four parts by measure of water, with one part by measure of Ammonia.

60.—SULPHIDE OF AMMONIUM.—($NH_4\ S.$)—

Is evolved from decomposing animal matter, as in cesspools, with Hydrosulphuric Acid and Nitrogen. It is poisonous in much quantity. Chlorine or Chloride of Lime is an antidote.

It is also called Hydrosulphuret of Ammonia, Hydrosulphate of Ammonia, Sulphuret of Ammonium, &c. It is prepared by passing Hydrosulphuric Acid Gas (HS) into water of Ammonia to perfect saturation, that is until it no longer produces a precipitate in a solution of Magnesia.

It has a greenish yellow color, a very fetid odor, and an acrid disagreeable taste. The Mineral Acids decompose it, evolve Hydrosulphuric Acid and precipitate Sulphur.

With the Salts of Lead, Bismuth, Silver, and Copper, it produces black precipitates. With those of Antimony red; Cadmium and Tin (the Persalts) and with the Arsenites (on addition of an Acid) yellow; with the Salts of Zinc, white. All these precipitates are Sulphurets (Sulphides) of the respective metals.

By exposure to the air it attracts Oxygen and deposits Sulphur, and its action on metallic solutions is then considerably modified. For example, if 2 or 3 fluid drachms be exposed to the air in a wine glass for a day or two, the solution will then be found to have the property of causing a red precipitate with the Salts of Lead, yellow with Tartar Emetic, and white with Arsenious Acid.

Caustic Potash causes in it the evolution of Ammonia.

It is chiefly used in Analysis to precipitate Cobalt, Nickel, Manganese and Zinc. Also Alumina, Chromium and Iron. The Phos-

phates of Alumina, Baryta, Strontia, Lime and Magnesia, and the Oxalates of Baryta, Strontia and Lime.

It may be used dilute with three parts of water.

61.—CHLORIDE OF AMMONIUM.—(NH_4Cl)—

Called also Muriate of Ammonia, Sal Ammoniac and Hydrochlorate of Ammonia.

This Salt may be usually found crystallized in Cubic or Octahedral crystals at the unburnt ends of brick kilns, where fuel made of animal manure (goba) has been used.

It is prepared by the destructive distillation of bones; It has no odor, and a saline, acrid and cool taste. When heated, it sublimes without undergoing fusion or decomposition. It is soluble in about 3 parts of cold and 1 of boiling water, cold being produced during the solution, hence its employment in freezing mixtures. It dissolves in Alcohol.

Muriate of Ammonia is liable to no alteration from air, and may be kept a long time without change.

A mixture of two parts of this Salt with five parts Nitrate of Potash (Saltpetre) and sixteen parts of water, should lower the Thermometer from 50° to 10° Fahrenheit.

It may be thus recognized. It is white and volatile, and if heated on the point of a knife by the flame of a candle, it readily sublimes. Mixed with Caustic Potash or Quick Lime, it evolves Ammoniacal Gas, which is known by its odor, its action on Turmeric paper and its fuming with the vapor of Hydrochloric Acid. Dissolved in water, it produces with Nitrate of Silver the white precipitate of Chloride of Silver, and with Chloride of Platinum, the yellow precipitate beforementioned (under head Ammonia), which when collected, dried and ignited, yields spongy Platinum.

Chloride of Ammonium is much used in Analysis, being employed to precipitate Alumina, Chromium, Iron, Zinc, Manganese, Nickel and Cobalt, also Phosphate of Alumina, Phosphate of Iron, and the Phosphates and Oxalates of the Alkaline Earths.

To detect Phosphoric Acid, it is used in conjunction with and to assist Sulphate of Magnesia; Phosphate of Magnesia and Ammonia, being almost insoluble in water containing Ammonia, but slightly soluble in pure water.

On adding Chloride of Ammonium to a solution of an Alkaline Silicate, a gelatinous precipitate takes place of hydrated Silicic Acid.

It is used to separate Alumina from Alkaline solutions. The Alkali combines with the Hydrochloric Acid, and the liberated Ammonia determines the precipitation of the Alumina, which after being washed and dried is perfectly pure.

It may be used, one by weight to 10 by measure of water.

62.º—POTASH.—(*KO.*)

In the Inorganic Kingdom, Potash is found in combination with Sulphuric, Nitric, Silicic and perhaps Carbonic Acids. As an ingredient of rocks, it is more abundant than Soda.

In the Organic, it is met with in combination with Phosphoric, Sulphuric, Nitric, Carbonic and various Organic Acids. It occurs more abundantly in vegetables than in animals.

The ashes of trees and of herbaceous plants growing elsewhere than on the sea-shore, contain the Carbonate of Potassa, and such is the sufficient proof of the existence of Potassium generally throughout the vegetable kingdom. The proportion of Potassium varies considerably in different plants, and those which contain a large proportion, refuse to grow in soils not rich in Salts of Potassa.

In the animal kingdom, Potash is not found so extensively diffused.

Solid Potash (Potassa Fusa or Hydrate of Potash) is white, and, if pure, dissolves in both Water and Alcohol. During the solution in water heat is evolved. Its solubility in Alcohol enables us to separate it from the Carbonate and Bicarbonate of Potash, both of which are insoluble in this liquid. It has a strong affinity for water, which it rapidly attracts from the atmosphere, and in consequence becomes liquid. At a low red heat it fuses, and at a higher temperature is volatilized. It is odorless, but has a caustic urinous taste. It rapidly decomposes Organic substances. It is the basis of all soft soaps, as Soda is of hard soaps.

The liquid from it has a soapy feel between the fingers. It strongly attracts Carbonic Acid from the atmosphere, and therefore should be kept in close vessels. On account of this property, it is used to detect the presence of Carbonic Acid. It corrodes flint glass, and is on that account directed to be kept in green glass bottles.

Potash, free or combined, is recognized by the following characters. The Hydro-sulphurets, Ferro-cyanides and Carbonates produce no precipitate with it. Tartaric (in excess) and Perchloric Acids occasion precipitates of the Bitartrate and Perchlorate of Potash. Chloride

of Platinum throws down a yellow precipitate with Potash or its Salts. Lastly, the Potash Salts communicate a violet tinge to the flame of Alcohol.

It reddens Turmeric, and restores Litmus reddened, to its blue color; Its Sulphides and Carbonates act similarly on vegetable colors.

It does not whiten Lime water.

It has the property which makes it useful in Analysis of dissolving Alumina. Soap Lye has also been used for the same purpose.

If impure with Carbonate of Potash, this will be detected by Lime water or an Acid which will disengage the Carbonic Acid.

It cannot be detected in the presence of Ammonia or any of its Salts, because the same re-agents which precipitate Potash from its solutions, form also with Ammonia a corresponding class of insoluble substances: the latter must therefore be separated from the substance before proceeding to test for the former.

Its presence in a solution may be thus tested; by evaporating to dryness, and igniting to volatilize any Ammoniacal Salts present; if a residue remain, a portion of it is to be placed upon the loop of a Platinum wire and exposed to the inner blowpipe flame. If the flame be colored yellow, Soda is present; if violet, it proves the absence of Soda, and the probable presence of Potash; but if Soda be present, (or Lithia,) the test by the violet color imparted to the outer flame fails.

The remainder of the substance is to be dissolved in the smallest possible quantity of water, and examined for Potash, by adding Tartaric Acid to the solution, which produces, in solutions of that Alkali, a crystalline precipitate Bitartrate of Potash ($KO, HO\ \bar{T}$); any solution subjected to this test should be neutral or Alkaline, the precipitate being soluble in free Alkalies and free Mineral Acids.

63.—NITRATE OF POTASH.—(KO, NO_5.)

Saltpetre is found in the soil in all parts of the world. Some have thought that the Nitric Acid of the Salt was formed by the union of the Nitrogen and Oxygen of the atmosphere; others have supposed the presence of animal matter necessary to yield by its decomposition Nitrogen, but this is not invariably the case. The Potash of the Nitre is in most cases easily accounted for, being found in some of the constituents of the soil, namely, Felspar and Mica.

It is chiefly procured from India, especially Tirhoot, where it is manufactured from the natural production for exportation. It is most abundant in those parts containing a redundancy of Carbonate of Lime.

It usually crystallizes in six-sided prisms, when pure; the crystals are transparent, colorless and undergo no change by exposure to the air.* It fuses when heated. One hundred parts of water at 77° dissolve 38 parts of the Salt, which is insoluble in pure Alcohol.†

Dissolved in 300 times its weight of water, it promotes vegetation, but a solution containing $\frac{1}{30}$ part of Nitre is injurious to the growth of plants.

It is employed together with Muriate of Ammonia for cooling mixtures, and is also used as a flux, in conjunction with Carbonate of Soda, &c.

64.—CHROMATE OF POTASH.—(KO, Cr^2 O_3.)

Chromic Acid is extracted from the Red Lead Ore of Siberia, (Minium or Binoxide of Lead) by treating it with Carbonate of Potash and separating the Alkali by means of a more powerful Acid.

Chromium (from χρωμα, color) is remarkable for giving color to its combinations, which with the Acids, form insoluble Salts in water, but nearly all soluble in Nitric Acid

Oxide of Chromium is principally extracted from Chromic Iron ($Fe\ O$, $Cr_2\ O_3$) which is found in Sweden, the Ural Mountains and America.

It is used as a test for Lead in solutions of which Chromate of Potash produces a yellow precipitate of Chromate of Lead, ($Pb.\ O$, $Cr_2\ O_3$) soluble in the fixed Alkalies, (Potash and Soda,) but insoluble in Nitric Acid.

Chromate of Potash throws down from solutions of Bismuth, the yellow Chromate, which differs from that of Lead by being soluble in Nitric Acid, and not in Potash. It is used in conjunction with Sulphuric Acid to detect Chlorine (see Hydrochloric Acid.)

Also for Baryta in neutral and Alkaline solutions, of which it produces a pale yellow precipitate of Chromate of Baryta, ($Ba\ O$, $Cr\ O_3$) insoluble in the Alkalies and Acetic Acid.

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* Analysis by Mr. Stevenson, J. As. Soc. Vol. 2, p. 23.

Matter insoluble in 3 Acids Silex,	50.
Ditto Soluble Carbonate Lime,	44.3
Sulphate Soda,	2.7
Muriate Soda,	1.4
Nitrate of Lime,	.9
Ditto Potash,	.7
	100.

† Or 7 parts water at 60, dissolve 2 parts Nitre.

After ignition, Oxide of Chromium (as well as Alumina and Oxide of Iron) dissolves with great difficulty, even in the concentrated Mineral Acids.

It is used, one by weight, to eight by measure of water.

65.—SULPHATE OF POTASH.—(16) (KO, SO_3.)—

Is found in some Mineral Waters and in native Alum and Alum stone; some well waters (as Trafalgar Square well) contain it in considerable quantity; in the Organic Kingdom it has been found in the bulb of Garlic, Myrrh, Opium, &c. Also in blood and urine.

It crystallizes in single or double six-sided pyramids. It is hard, inodorous, has a saline bitter taste, and is unchanged by exposure to air. When heated it decrepitates. It requires 16 times its weight of water to dissolve it, and is insoluble in Alcohol.

It is decomposed by Tartaric Acid, which forms with it crystals of Bitartrate of Potash.

It is chiefly used to precipitate Strontia (separating it in a solution from Lime), for which purpose the solution should be as concentrated as possible, and time allowed for the precipitate to settle.

If a Fluoride mixed with Bisulphate of Potash is heated in a test tube, Hydrofluoric Acid is disengaged, which is easily detected by the etching of the glass.

It is also used to show the presence of Lead in Mineral Waters, where it is said to detect the one millionth part of the weight of the water.

66.—FERRO-CYANIDE OF POTASSIUM.—($Kcfy$)—Yellow Prussiate of Potash.

Called also Prussiate of Potash, Ferro-prussiate of Potash, and Ferro-cyanate of Potash.

It crystallizes in large beautiful lemon yellow transparent permanent inodorous crystals, whose primary form is an Octahedron with a square base. They have a peculiar toughness or flexibility somewhat analogous to Selenite, and a sweetish, yet somewhat bitter saline taste.

It is insoluble in Alcohol, but dissolves readily in hot or cold water.

Hydro-Sulphuric Acid, (HS) the Sulphurets, Alkalies, or Tincture of Galls (an old test for Iron) give no precipitate with a solution of this Salt, showing that the Iron which it contains is in some remarkable state of combination.

It is used as a test for Iron, one to 12 of water, and produces in solutions of Protoxide of Iron a white precipitate of Ferro-Cyanide of

Iron and Potassium, (2 *Cfy*, *K*, 3 *Fe*,) which speedily becomes blue by absorption of Oxygen from the air.

From solutions of the Per or Sesquioxide of Iron, even if very dilute, it throws down a beautiful blue precipitate of Ferro-cyanide of Iron, (Prussian blue Fe_4 Cfy_3) which is insoluble in Acid, but is decomposed by Potash.

From very dilute solutions even of Copper, it throws down a reddish brown precipitate of Ferro-cyanide of Copper, (*Cu*, *Cfy*.) which is insoluble in dilute Acids, but is decomposed by the fixed Alkalies.

In testing with this Salt for Iron, it must be remembered that the solution must not be Acid, as the Ferro-cyanides are decomposed by the Mineral Acids, forming green colored solutions. It is necessary, therefore, in order to avoid error when testing for Iron in Acid solutions, to add previously an Alkaline Acetate, so as to render the solution very slightly Alkaline.

67.—FERRI-CYANIDE OF POTASSIUM.—(KCy_6 Fe_2)—Red Prussiate of Potash.

If Chlorine be passed through a solution of Ferro-cyanide of Potassium, it abstracts one equivalent of Potassium from every two equivalents of the Ferro-cyanide, by which one equivalent of the Ferro-sesquicyanide or Ferri-cyanide of Potassium is formed in solution, and by evaporation this Salt may be obtained in the form of *red* crystals, which throw down a blue precipitate with the Protosalts of Iron, but occasion no change with the Persalts.

The precipitate with the Protoxide of Iron, Ferri-cyanide of Iron (2 *Cfy* + 2 *Fe*) is insoluble in Hydrochloric Acid, but is decomposed with precipitation of Oxide of Iron by Potash.

With the Peroxide of Iron, if much of it be present, it deepens the color of the solution to a ruddy brown; if only small traces be present it renders the solution green. In no case does a solution of Peroxide of Iron yield a precipitate with this re-agent.

It is used dilute, one to twelve of water.

68.—CYANIDE OF POTASSIUM.—(*KO. Cy.*)—

Is chiefly used as a flux in conjunction with Carbonate of Soda and the other fluxes, but not to Nitrates or Chlorates, as it will explode with them.

It is also much used in the practice of Daguerrotyping, to remove stains of Nitrate of Silver from the hands, but being highly poisonous, care is requisite not to apply it where the surface of the skin

has been injured. A soap prepared from it, called Cyanogen soap, is also used.

In Analysis it is employed in the separation of Nickel and Cobalt. The solution containing them, being acidified with Hydrochloric Acid, Cyanide of Potassium is added in excess, and it is then boiled for some time. Filter if necessary, and add dilute Sulphuric Acid. If a light greenish precipitate form either immediately or after the lapse of some time, it is a proof that Nickel is present. This yellowish green precipitate is Cyanide of Nickel (*Ni Cy*), which re-dissolves in an excess of the Cyanide precipitant, a double Salt of Cyanide of Nickel and Cyanide of Potassium being formed. On the addition of Hydrochloric or Sulphuric Acid to a solution of this double Salt, the Cyanide of Nickel is re-precipitated, whilst the Cyanide of Potassium is decomposed, Hydrocyanic Acid being evolved.

Cyanide of Potassium produces in solutions of Cobalt, a brownish yellow precipitate of Cyanide of Cobalt (*Co Cy*), which re-dissolves in an excess of the precipitant. From this solution it is not re-precipitated on the addition of Acids. It precipitates the Persalts of Iron *blue*, the Salts of Binoxide of Copper *apple green*, and Nitrate of Silver *white*, (the Cyanide of Silver white, clotty, insoluble in water or cold Nitric Acid, though it dissolves in boiling Nitric Acid and also in Ammonia.)

69.—CARBONATE OF POTASH.—($KO.\ CO_2$)—Salt of Tartar, Mild Vegetable Alkali, Fixed Nitre, &c.

Is but little used except as a flux in conjunction with Carbonate of Soda, &c., and in the reduction of Silica by fusion.

From the Bicarbonate of Potash, it is distinguished by its causing a brick red precipitate with a solution of Bi or Perchloride of Mercury, the precipitate being Percarbonate of Mercury.

Sulphate of Magnesia produces a white precipitate with the Carbonate of Potash, and not with the Bicarbonate.

It is sometimes impure with Silicic Acid, which may be detected by supersaturating with Hydrochloric Acid, evaporating and igniting the residue. The Silicic Acid is insoluble in water.

Chloride and Sulphate impurities may be detected by supersaturating with Nitric Acid, and testing the solution with Nitrate of Silver, or Chloride of Barium, as usual.

70.—CARBONATE OF SODA.—($NaO.\ CO_2$) Mineral Alkali, Sub-Carbonate of Soda.

Soda is more particularly the Alkali of the animal kingdom. Chloride, Sulphate and Phosphate of Soda being met with in the animal fluids.

It is found in crystals or in the form of an efflorescent powder, and is a constituent of some mineral waters, which are, in consequence, termed Alkaline. It is insoluble in Alcohol.

It is used chiefly as a flux in Analysis. The best test for Soda is the blowpipe flame, to which it imparts a yellow color.

Caustic Soda is used like Caustic Potash in solution in the cold to precipitate Iron, Manganese, Nickel, Cobalt. It also precipitates (as Potash also does) Alumina, Chromium and Zinc, but these are soluble in an excess of the re-agent.

Caustic Soda is thus prepared from the Carbonate.

Dissolve one part by weight of Carbonate of Soda in 12 parts by measure of water, and boil the solution in a clean Iron pan. Hydrate of Lime must be added in small portions to the boiling liquid until Hydrochloric Acid causes no effervescence in a portion of the liquid. When this point has been attained, the pan must be removed from the fire and the precipitate allowed to subside. The supernatant liquid must then be drawn off by means of a Syphon, or passed through a filter of bleached linen, and the filtrate evaporated rapidly over a quick fire until it has been reduced to half its original bulk. On supersaturating a portion of the liquid with Hydrochloric Acid, no, or only a slight, effervescence should take place. The solution must be kept in well-stoppered bottles.

The Alkaline Carbonates and Ammonia, throw down the Oxide of Tin from solution as Hydrate. The precipitate is soluble in solutions of the fixed Alkalis.

Soda and Potash precipitate Lead, Mercury and Silver from their solutions.

The Hydrate of Lead (precipitate) is with difficulty soluble in an excess of the re-agents. The precipitate produced by them in solutions of the Peroxide of Mercury is the yellow Hydrate, unless Salts of Ammonia are present; in that case the precipitate is the same as that produced by Ammonia.

They also precipitate Bismuth, Cadmium and Copper. If added to solutions of Copper in the cold, they produce a basic Carbonate; but if the solution is boiled, it is converted into the black Oxide.

Carbonate of Soda is used to discover Hydrocyanic, Hydrobromic, and Hydriodic Acids, when they have to be looked for in a substance insoluble in water. A portion of the original substance should then be boiled in a solution of Carbonate of Soda; by this means the insoluble Salts are decomposed, the acid passing into solution along with the Soda, whilst the base remains behind in the residue.

The Soda solution must be rendered perfectly neutral by Nitric Acid before testing for these Acids.

When a solution is Acid, the acidity may proceed from the presence of a free Acid, an Acid Salt, or a neutral Salt having an Acid re-action. To ascertain to which of these causes the acidity is due, place the end of a glass rod moistened with a solution of Carbonate of Soda into a portion of the fluid in a watch glass. If the solution becomes turbid and remains so, it is due to the presence of a neutral Salt; if it becomes clear again, the re-action is due either to an Acid Salt or a free Acid. Carbonates and Sulphides cannot be present in an Acid solution.

Potash produces no effect on Salts of Soda, nor do Tartaric and Chloric Acid, and Sulphate of Alumina, nor does Perchloride of Platinum in moderately dilute solutions.

Antimoniate of Potash produces a white precipitate.

It is used generally dilute, 1 to 10 of water.

71.—PHOSPHATE OF SODA.—($2\ NaO,\ HO,\ PO_5$).

Is found in some mineral waters in small quantities, and in many animal fluids, especially urine.

With Nitrate of Silver it occasions a yellow precipitate, soluble both in Nitric Acid and Ammonia.

The Phosphoric Acid in it may be recognized as follows: A solution of the Phosphate throws down a white precipitate with Acetate of Lead, as well as with Chloride of Barium. The precipitate in both cases is a Phosphate, and dissolves in Nitric Acid without effervescence.

Hydrosulphuric Acid, as well as the Hydrosulphates, occasion no change in a solution of Phosphate of Soda.

Phosphate of Soda produces in concentrated solutions of Magnesia a precipitate of Phosphate of Magnesia. A more insoluble Magnesian salt may be produced by adding along with the Phosphate of Soda, Chloride of Ammonium and Ammonia. The precipitate in this case being Phosphate of Magnesia and Ammonia ($2\ Mg\ O,\ NH_4\ O,\ PO_5$) which is soluble in free acids.

Phosphate of Magnesia and Ammonia and Arseniate of Magnesia and Ammonia, are the only Magnesian Salts which are insoluble in aqueous solutions containing Salts of Ammonia.

It is sometimes used in the precipitation of Alumina.

72.—BIBORATE OF SODA—($NaO.\ 2\ BO_3$)—Borax.

Borax is a substance peculiar to the mineral kingdom. It has been found in some mineral waters. It occurs also in the waters of certain lakes, especially those of Thibet and Persia.

If to a strong hot solution of Borax, Sulphuric Acid be added, till the liquor is sour to the taste, Boracic Acid will be deposited in crystals as the liquid cools.

It is much used as a flux, especially in blowpipe operations.

Boracic Acid possesses the peculiar property of affecting Turmeric paper in the manner of a free Alkali, as well as Litmus paper like other acids.

An Alcoholic solution of Boracic Acid burns with a green colored flame, which becomes more distinct upon stirring the mixture. To detect a Borate, add to the substance under examination strong Sulphuric Acid and Alcohol or wood Naphtha; ignite the mixture subsequently. If a Borate be present the borders of the flame will appear green, which becomes more distinct upon stirring, and the delicacy is further increased by repeatedly extinguishing and re-kindling the flame. The only substance which at all interferes with this test is Copper, the salts of which impart the same color to the flame. This metal, if present, must therefore be got rid of by Sulphuretted Hydrogen before testing for Boracic Acid.

73.—PHOSPHATE OF SODA AND AMMONIA.—($NaO, NH_4O. HO. PO_5$.)

Or Microcosmic Salt, is chiefly employed as a flux in blowpipe Analysis. It is also called Salt of Phosphorus. It is of great utility.

74.—SULPHATE OF MAGNESIA.—(MgO, SO_3)—Epsom or Seidlitz Salts.

It is a constituent of sea and many mineral waters. It occurs as an efflorescence on other minerals.

Dolomite, or Magnesian Limestone, is a compound of Carbonate of Lime and Carbonate of Magnesia. Bittern is the residual liquor of sea water, from which common salt (Chloride of Sodium) has been separated. It contains Chloride of Magnesium and Sulphate of Magnesia.

Magnesia is very slightly soluble in cold, and still less in hot, water. It is soluble in the dilute mineral acids without effervescence.

The solution does not occasion any precipitate with the Ferrocyanides, Hydro-sulphurets, Oxalates or Bicarbonates. The neutral Alkaline Carbonates, when unmixed with any Bicarbonate, throw down a white precipitate. Ammonia, with Phosphate of Soda, causes a white precipitate (or Phosphate of Soda and Ammonia in a neutral or Alkaline solution) of Ammoniacal Phosphate of Magnesia. Magnesia is insoluble in alkaline solutions, and is thereby distinguished from Alumina.

5. It is used to detect the Phosphate of Alumina (which, unlike pure Alumina, is insoluble in Acetic Acid) thus—Dissolve the compound in Hydrochloric Acid, then add Tartaric Acid and then Ammonia in excess. If on addition of Sulphate of Magnesia to this solution a precipitate be formed, Phosphoric Acid is present. When the quantity of acid present is small, the precipitate will not appear until after the lapse of some time; in all cases the formation of the precipitate is much promoted by agitation.

It is also used in the detection of the Phosphates of Lime (Bone Earth) Baryta, Strontia, and Magnesia. Thus,—Dissolve the Phosphate compound in a small quantity of Nitric Acid, add to this solution Protonitrate of Mercury and then Ammonia slightly in excess; Phosphate of Mercury, along with the excess of Oxide of Mercury, will be precipitated, whilst the Lime will remain in solution from which it will be thrown down by Oxalic Acid. Boil the mixed precipitate of Phosphate and Oxide of Mercury in Sulphide of Ammonium; filter and to the filtrate add Chloride of Ammonium and Sulphate of Magnesia, if a precipitate be produced, it proves the presence of Phosphoric Acid.

Sulphate of Magnesia in the presence of Chloride of Ammonium and Ammonia produces, in solutions of the Arseniate, a white precipitate of Arseniate of Ammonia and Magnesia ($2\ Mg\ O, NH_4\ O, As\ O_5$) soluble in Acids.

Sulphate of Magnesia or any soluble Magnesian Salt, produces in aqueous solutions of the Phosphates, if concentrated, a white precipitate of Phosphate of Magnesia ($2\ Mg\ O, HO, PO_5$.) A Salt much more insoluble in water is produced by adding Chloride of Ammonium, Ammonia and then the Magnesian Salt; in this way Phosphate of Magnesia and Ammonia is precipitated, which is slightly soluble in pure water, but almost insoluble in water containing Ammonia. In dilute solutions it only appears after much agitation and the lapse of some time. This test can only be applied when the Phosphates are soluble in Ammoniacal solutions.

75.—NITRATE OF SILVER—($Ag\ NO_5$)—Lunar Caustic, Lapis Infernalis.

When heated it fuses, and if the temperature is increased, decomposes. Nitric Acid and Oxygen are evolved leaving Metallic Silver. It does not deliquesce. When exposed to the atmosphere and solar light, it blackens. In a clean dry glass tube, hermetically sealed, it undergoes no change of color by exposure to solar light. The contact of

Organic matter readily occasions it to become black. It blackens the fingers, clothes, &c.

It is chiefly used to detect Chlorine (whether in Hydrochloric Acid or otherwise.) The precipitate formed of Chloride of Silver being very readily formed and detected. The delicacy of this test is astonishing, one grain of Salt in 42,250 grains of water, will produce the characteristic white cloudiness.

Nitrate of Silver produces, in neutral solutions of the Arsenites, a yellow precipitate of Arsenite of Silver ($2\ Ag\ O,\ As\ O_3$) soluble in Nitric Acid and Ammonia. In neutral solutions of the Arseniates, it produces a reddish brown precipitate of Arseniate of Silver ($3\ Ag\ O,\ As\ O_5$) soluble in dilute Nitric Acid and in Ammonia.

Besides Chlorine, Nitrate of Silver is used to detect the presence of Bromine, Iodine and Cyanagen, with which it forms precipitates, such precipitate, when produced in any solution, must be digested in Nitric Acid, which well dissolve all the Silver Salts, with the exception of the Chloride, Cyanide, Bromide and Iodide of Silver.

To ascertain still further which of these substances are present, the Silver precipitate (insoluble in Nitric Acid) must, after being washed, be digested in dilute Ammonia; the Chloride and Cyanide of Silver, being soluble in that re-agent, will dissolve, whilst the Bromide and Iodide, being insoluble, will remain undissolved. To the filtered solution must be added Nitric Acid in excess. If no precipitate is formed it shows the absence of Chlorine and Cyanagen. The further separation of these is an intricate process.

76.—PROTONITRATE OF COBALT—($Co\ O.\ NO_5$)—

Is used entirely in blowpipe Analysis, its action upon some of the Metals, after they have been moistened with it, being peculiar.

If Alumina or any of its compounds be ignited to a white ash upon charcoal by the blowpipe flame, afterwards moistened with a few drops of Protonitrate of Cobalt, and again strongly heated, the mass assumes a blue color on cooling, which is characteristic of Alumina.

Zinc shows a green, Magnesia a pink, and Binoxide of Tin, a bluish green color.

77.—NITRATE OF LEAD.—($Pb\ O\ NO_5$.)

In a solution of Nitrate of Lead, the Alkalies, their Carbonates, Sulphuric Acid, and the Sulphates and Ferro-cyanide of Potassium, produce white precipitates. Chromate of Potash and Iodide of Potassium occasion yellow precipitates. Hydrosulphuric Acid and the Hydrosulphates form black precipitates of the Sulphuret of Lead, and a piece of Zinc throws down Metallic Lead in an arborescent form.

Acetate of Lead is often preferred to the Nitrate. (The Subacetate is Goulard's extract.) It may be used to detect the adulteration by Sulphuric Acid of pickles, lemon juice, &c. For when added to these a white precipitate is formed, which if merely the Citrate or Malate of Lead, will be re-dissolved on the addition of a few drops of strong Nitric Acid, but if the lemon juice was mixed with Sulphuric Acid, the white Sulphate of Lead will remain at the bottom, in which 100 parts of Sulphuric Acid indicate 71 of Lead.

Subacetate of Lead is used to distinguish mucous from gelatine in animal matters. With the former it instantly produces a copious white, and flaky precipitate, but it is not sensibly rendered turbid by a solution of animal gelatine.

It (or any soluble Salt of Lead) is used to test the presence of Hydrosulphuric Acid. When boiling a solution to expel this gas, a paper, moistened with a solution of the Salt of Lead, should be held over the mouth of the tube. If the paper be not blackened, all the gas has been volatilized.

It is also used, in common with the other soluble Salts of Lead, to detect Iodine, with which it precipitates an orange yellow precipitate of Iodide of Lead.

It also precipitates Arsenic as the Arseniate of Lead.

78.—SULPHATE OF COPPER—($CuO.\ SO_3$)—Blue Vitriol, Blue Copperas, Blue Stone and Bisulphate of Copper—

May be prepared by evaporating the water found in, or issuing from Copper Mines. When heated it loses its water of crystallization, and becomes a white powder. By a very intense heat it is decomposed, Sulphurous Acid and Oxygen are evolved, and Oxide of Copper left. It is insoluble in Alcohol.

If impure with Sulphate of Iron, as it sometimes is, this may be detected by excess of Ammonia, which throws down the Oxide of Iron, but dissolves the Oxide of Copper.

It is useful in preventing dry rot in timber, which has been soaked in it.

Sulphate of Copper produces in neutral solutions of the Arsenites a yellowish green precipitate of Arsenite of Copper ($2\ CuO,\ As\ O_3$.)

It is useful in distinguishing Arsenious from Arsenic Acid, with the aid of Caustic Potash (*see* Potash.)

In neutral solutions of the Arseniates it produces a greenish blue precipitate of Arseniate of Copper ($2\ CuO,\ HO,\ As\ O_5$.)

79.—CHLORIDE OF BARIUM—($Ba\ Cl$)—Muriate of Barytes.

In dry warm air the crystals effloresce, but in the ordinary states

of the air, they undergo no change. When heated they decrepitate, lose their water of crystallization, and at a red heat fuse. It is soluble in water, insoluble in Alcohol.

Its aqueous solution should undergo no change of color by the addition of Ferrocyanide of Potassium, Hydrosulphuric Acid or Caustic Ammonia, by which the absence of matter (as Iron, Lead or Copper) may be inferred. If excess of Sulphuric Acid be added, the filtered solution should be completely volatile when heated, and should occasion no precipitate on the addition of Carbonate of Soda by which the absence of Lime or Magnesia is proved.

It is decomposed by the Carbonated Alkalis which, if in excess, would produce a precipitate of Carbonate of Barytes in addition to any Sulphate of Barytes also produced. But the precipitate is soluble in dilute Hydrochloric or Nitric Acid, and may be prevented by adding to the solution to be assayed a few drops of Hydrochloric Acid; or the two precipitates may be separated by mere digestion in dilute Hydrochloric Acid which removes the Carbonate, but does not touch the Sulphate.

It is chiefly used as a test for Sulphuric Acid. Sulphate of Baryta, from its insolubility in Acids, is at once distinguished from all the other Baryta Salts; any soluble Salt of Baryta is therefore the best and most delicate test for Sulphuric Acid.

If however it be applied to concentrated Nitric Acid, a crystallized precipitate of *Nitrate* of Barytes is produced which is owing to the more sparing solution of the Nitrate, than the Chloride of, Barium. The precipitate being soluble in water may be thus distinguished from Sulphate and Carbonate of Barytes. This should be held in mind if Nitric Acid is being tested to ascertain the presence of Sulphuric Acid in it or not.

Nitrate of Barytes is useful to discover the Alkalis, Potash or Soda, when occurring in fossils.

80.—PROTOCHLORIDE OF TIN.—(*Sn Cl.*)

Can be obtained by boiling Tin in strong Hydrochloric Acid.

In a solution of it, Potash causes a white precipitate soluble in excess of the precipitant, Hydrosulphuric Acid a brown; and Chloride (perchloride) of Gold a purple precipitate, insoluble in Hydrochloric Acid (the purple powder of Cassius,) the presence of a little free Nitric Acid assisting it.

It is a delicate test for Platinum, with the solutions of which it produces an orange colored precipitate.

To produce the purple precipitate with Gold, it is necessary that the

Protochloride of Tin be freshly prepared (or at the minimum of oxidation.) It thus attracts more readily the Oxygen from the Gold. If the Tin be in excess, the precipitate is more of a rose color.

If Protochloride of Tin be heated with Nitric Acid, we obtain a perchloride which causes a yellowish precipitate with Hydrosulphuric Acid.

The Protosalts of Tin are colorless and are decomposed by heat. The soluble neutral Salts redden Litmus paper, and are decomposed in the presence of much water into soluble Acid and insoluble Basic Salts. The addition of water therefore to the Protosalts of Tin produces a milkiness, which disappears on the addition of Hydrochloric Acid.

All Protosalts of Tin are powerful reducing agents, from the great affinity they have for an additional quantity of Oxygen. Many Metallic Oxides, such as the Oxides of Gold, Silver and Mercury, are reduced to the Metallic state in their presence, whilst other Oxides, such as Peroxide of Iron and Oxide of Copper, are reduced to a lower degree of oxidation.

81.—PERCHLORIDE OF GOLD—($Au\ Cl_3$)—Chloride or Terchloride of Gold.

It is reduced by many Metals, as Iron, Copper, Tin, Zinc, &c.; by some Metallic Salts, as Protosulphate of Iron; and by many Organic bodies, as Charcoal, Sugar, Gum, all of which therefore are incompatible with it. Nitrate of Silver occasions a precipitate of Chloride of Silver and Oxide of Gold. Hydrochloric Acid removes the latter.

82.—PERCHLORIDE OF PLATINUM—($Pt\ Cl_2$) or Bichloride.

Is used as a test for Potash, in neutral and acid solutions of which it produces a yellow crystalline precipitate, a double salt of Chloride of Potassium, and Chloride of Platinum, ($KO, Pt\ Cl_2$). The presence of free Hydrochloric Acid promotes the formation of this precipitate. It is slightly soluble in water, but wholly insoluble in Alcohol.

83.—PERCHLORIDE OF IRON—($Fe_2\ Cl_3$)—Sesquichloride—

Is prepared by dissolving recently precipitated and well washed Peroxide of Iron in Hydrochloric Acid. It must not contain any free Acid.

It is used in the separation of Phosphate of Lime. Dissolve the Phosphate in a small quantity of Hydrochloric Acid; add to the solution Acetate of Potash, and after that a few drops of Perchloride of Iron; Phosphate of Iron will be precipitated, whilst the Lime will remain in solution along with the excess of the Perchloride of Iron employed. To detect the Lime, throw down the Iron by Sulphide of Ammonium,

and add to the filtrate Oxalic Acid. If a precipitate be produced Lime is present.

Also in detecting Phosphoric Acid, thus:—If a solution containing Phosphoric Acid, be slightly acidulated with Hydrochloric Acid (if it be not already Acid) and afterwards a few drops of Perchloride of Iron be added, and finally Acetate of Soda in excess, a white gelatinous precipitate of Perphosphate of Iron will be produced, which is soluble in free mineral Acids, but insoluble in Acetic Acid. Should the quantity of Phosphoric Acid be very minute, the precipitate will appear only after the lapse of several hours. Care must be taken not to add too much Perchloride of Iron, because Perphosphate of Iron is rather soluble in Peracetate of Iron. This test requires therefore the following modification, when large quantities of Peroxide exist in the substance under examination. To the Acid solution add Acetate of Soda in excess and then boil; by this means the whole of the Iron will be thrown down, in combination with Acetic and Phosphoric Acids. After having filtered and washed the precipitate, digest it in Sulphide of Ammonium; by this means the Iron is converted into insoluble Sulphide, whilst the Phosphoric Acid passes into solution in combination with Ammonia. Test the Ammoniacal filtrate for this Acid by means of Chloride of Ammonium and Sulphate of Magnesia.

The Persalts of Iron impart to solutions of the Acetates a blood red color.

84.—PERCHLORIDE OF MERCURY.—(*Hg. Cl.*) Bichloride, Corrosive Sublimate. The Protochloride is Calomel.—(Hg_2 *Cl*).

Heated in a tube by a spirit lamp with Caustic Potash, an Alkaline Chloride is formed, Oxygen gas is evolved, and Metallic Mercury is sublimed and condensed in the form of globules on the sides of the tubes.

Lime Water causes a lemon yellow precipitate; an additional quantity of the precipitant water produces a brick dust red precipitate, while a further quantity restores the yellow color. The yellow colored precipitate is the Hydrated binoxide; the reddish colored precipitate is the Oxychloride.

Caustic Ammonia, added to a solution of Bichloride, causes Hydrochlorate of Ammonia to be formed in solution, while a white powder is thrown down (Ammonio-Chloride of Mercury.)

The Alkaline Carbonates throw down a brick-dust colored precipitate; the Bicarbonates a white one.

Protochloride of Tin occasions, with Perchloride of Mercury, a white precipitate of Calomel, while Perchloride of Tin remains in solution.

Very shortly this Protochloride of Mercury is converted into reguline Mercury, which falls down in a finely divided state as a greyish powder.

Ferro-cyanide of Potassium causes a white precipitate (Ferro-cyanide of Mercury.)

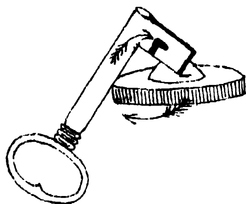
Corrosive sublimate is remarkable for the facility with which it dissolves in Ether, which removes it from water and all other liquids, so that if we wish to recognize the presence of the poison in any liquid, it is sufficient to shake it up with a quantity of Ether equal to that of the liquid concerned. After shaking it for some minutes, the Ethereal solution is allowed to separate by rest, and is then poured off and evaporated spontaneously, and the corrosive sublimate, which remains, is recognized by the characters found in the table under the head Mercury.

It may also be detected by plates of clean Copper (*see* Mercury.)

It is used to detect Albumen, which it does by causing a cloudiness, if Albumen be present to the amount of $\frac{1}{1000}$ by weight.

If 3 grains of the Salt be entirely decomposed by any albuminous solution, it would indicate 10½ grains of Albumen.

Corrosive sublimate may be detected in a liquid by Galvanism. Drop the suspected solution on a piece of Gold (as a Sovereign), and apply a key so that it may touch simultaneously the Gold and the solution. An electric current is immediately produced, the Perchloride is decomposed, the Mercury attaches itself to the negative pole, namely, the Gold, while the Chlorine unites with the Iron of the positive pole to form Chloride of Iron. The silver stain left on the Gold is readily removed by heat.



The Perchloride differing from the Protochloride in being soluble, is easily separated from it, when both are present in a solution, by means of Hydrochloric Acid.

Perchloride of Mercury is used to detect Iodine, with which in solution it throws down a red precipitate of Periodide of Mercury (*Hg I*), which is soluble in an excess of the Perchloride or of Iodide of Potassium.

85.—SULPHIDE OF IRON.—(*Fe S.*)

Sulphide of Iron is prepared by projecting a mixture of 30 parts of Iron filings with 21 of flower of Sulphur in small portions at a time into a red hot crucible, replacing the cover after each addition. When the whole has been added, the ignition must be continued for a short time until the excess of Sulphur has been dissipated.

If the bottle be glass-stoppered and of opaque glass, or in a dark place, it will suffice for testing purposes for a month or two.

It is chiefly used in obtaining Sulphuretted Hydrogen, for which purpose broken up into small pieces, it is introduced, together with dilute Hydrochloric or Sulphuric Acid, into the apparatus before figured. As this gas is so necessary in Analysis, the Sulphide of Iron is required in some quantity. The water through which the gas is passed acquires the same precipitating power, and should therefore be carefully kept in bottles. Distilled water absorbs about $\frac{3}{4}$ its bulk of Sulphuretted Hydrogen, (Harrogate water contains only about $\frac{1}{12}$.)

86.—PROTOSULPHATE OF IRON.—($FeO.\ SO_3$.)

Is usually kept in Alcohol, as by exposure to the air Oxygen is absorbed; the crystals acquire first a yellowish and darker green tint (Sulphate of the black oxide), then slightly effloresce and become covered with a yellow crust, which subsequently becomes brownish.

It is used as a test for Gold, which it precipitates in the Metallic form from solution, and is also employed for the detection of Nitric Acid (which see.)

87.—ACETATE OF SODA.—($NaO.\ \bar{A}$.)—

May be procured by saturating Carbonate of Soda with distilled vinegar, evaporating the solution and crystallizing. In this process the Acetic Acid expels the Carbonic Acid with effervescence.

Or more simply by adding Acetic Acid to a concentrated solution of Carbonate of Soda, until all effervescence ceases. This solution must be free from Sulphuric Acid. In using, dilute one to four of water.

Exposed to the air at ordinary temperatures, the crystals undergo a little change, but in dry and warm air, they effloresce and become anhydrous. It is less deliquescent however than Acetate of Potash. It should be white and perfectly neutral to test papers, Litmus and Turmeric.

It is useful in testing for Iron with the Ferro-cyanides in an acid solution; to which it should be added so as to make it neutral or Alkaline before employment of the re-agent.

It is used to separate the Oxalate of Lime, from the Phosphates of Lime and Magnesia in a Hydrochloric solution, which it does by precipitating the first when added in excess, the two latter remaining in solution.

Together with Perchloride of Iron (which see) it is used in detecting Phosphoric Acid.

88.—PROTONITRATE OF MERCURY.—($Hg_2O.\ NO_5$).—
Is made by gently treating in a small flask, nine parts of Nitric Acid in conjunction with 10 parts of Mercury until the disengagement of Nitrous fumes ceases; the solution is then boiled for some time with the undissolved portion of the Mercury, care being taken to re-place the water lost by evaporation. The crystals, which separate on the cooling of the liquid, are dissolved in 20 parts of cold water, slightly acidulated with Nitric Acid. The fluid is then filtered if necessary, and the filtrate kept in a glass bottle, the bottom of which is covered with Mercury.

It detects free Ammonia by producing with it an ash grey or black precipitate. Also $\frac{1}{300000}$ part of Hydrochloric Acid in water by producing a white precipitate insoluble in Nitric Acid. Also Phosphoric Acid, producing with it a white precipitate of Phosphate of Mercury soluble in Nitric Acid. With the Sulphates it also produces a white precipitate, which becomes yellow on repeated affusion with hot water. With Chloride of Gold it produces a bluish black, and with Chloride of Platinum an orange colored precipitate.

It is used in the detection of the Phosphate of Lime, (*see* Sulphate of Magnesia) also with Sulphate of Lime in detecting Oxalic Acid.

Protonitrate of Mercury, throws down from solutions of the Iodides a yellowish green precipitate of Iodide of Mercury ($Hg\ I$).

89.—SULPHATE OF LIME—($CaO.\ SO_3$)—Gypsum, Selenite, Alabaster.

Is used in an Acetic Acid solution to precipitate Baryta from the other Earths, Strontia, Lime and Magnesia. If an immediate precipitate is caused, it is the Sulphate of Baryta (insoluble in Acids and Alkalies) but if a precipitate only after the lapse of some time, then it is probable that Strontia is present and Baryta absent. The Sulphate of Strontia ($Sr\ O,\ SO_3$) is almost absolutely insoluble in Acids and Alkalies.

The solution of Sulphate of Lime must always be added in the cold, as this re-agent is less soluble in hot than cold water. Time must be allowed for the formation of the precipitate produced by this re-agent in solutions of Strontia, the formation of which is much promoted by agitation.

It is used to detect Oxalic Acid with which it forms a precipitate of the Oxalate of Lime.

90.—NITRATE OF AMMONIA.—($AmO.\ NO_5$.)—
Is made by neutralizing Nitric Acid with Carbonate of Ammonia. The solution is evaporated until crystals begin to be deposited, and is then allowed to cool. The crystals are collected and placed in well stoppered bottles.

It is used in the separation of Antimony and Tin, after these have been precipitated by Carbonate of Ammonia, leaving the Sulphides of Arsenic in solution. The precipitate, after being well dried, must be mixed with three parts of Nitrate of Ammonia, and the mixture projected in small portions into a porcelain crucible containing two parts of Nitrate of Ammonia in a state of liquefaction.

After all fuming has ceased, the residue should be gently ignited for a short time and then allowed to cool. The residue must be subsequently heated with a saturated solution of Tartaric Acid. If complete solution takes place, Oxide of Antimony alone can be present. If a portion remain undissolved by the Tartaric Acid, it indicates the probable presence of Tin. When complete solution does not take place, the liquid must be filtered, and to the filtrate must be added Hydrochloric Acid, and subsequently Hydrosulphuric Acid. If an orange red precipitate be formed, Oxide of Antimony is present.

The substance insoluble in Tartaric Acid must be examined for Tin by fusing it with Carbonate of Soda and Cyanide of Potassium, and the Tin precipitated either by Nitric Acid or Caustic Soda.

91.—LIME WATER.

Is made by digesting recently prepared Hydrate of Lime for some time with cold distilled water, with frequent agitation of the mixture; allow the undissolved portion of the Lime to subside, decant subsequently and keep the clear fluid in well stoppered bottles.

It is frequently used as a test, and particularly for Carbonic Acid.

92.—ALCOHOL—Spirits of Wine.—($C_4\ H_6\ O_2$.)—

Is used as a solvent and also for the Spirit lamp in blowpipe and numerous other operations of Analysis. It has a strong affinity for water, hence it abstracts this fluid from the atmosphere, and precipitates from their watery solution those Salts (as Sulphate of Potash) which are not soluble in spirit; while on the other hand water precipitates from their Alcoholic solution those substances (as Resin and Oil) not soluble in water.

Alcohol should be colorless and transparent. Its freedom from other substances than alcohol or water is to be determined by the purity of its odor, by the absence of any Acid or Alkaline reaction, and by its easy and complete volatility. The presence of volatile Oil may be ascertained by strong Sulphuric Acid, which communicates a red color to this substance.

Alcohol may be rectified and strengthened by means of Chloride of Calcium which abstracts its water, (*see* Chloride of Calcium.)

93.—CHLORIDE OF CALCIUM—Muriate of Lime.—(*CaO. Cl.*)—

Is made by dissolving pure Carbonate of Lime in dilute Hydrochloric Acid. The solution thus obtained must be neutral to test paper; 5 oz. of chalk to ½ a pint of Acid and the like quantity of water, are the proportions; When the effervescence has finished, the filtered solution should be evaporated to dryness, and the residue fused in a crucible. While in the liquid state, it is to be poured on a clean flat stone, and when cold, broken into small pieces, and preserved in a well stopped bottle.

It is found in small quantity in sea and many mineral and well waters. It has also been detected in small quantities in vegetables.

Lime or the Oxide of Calcium exists widely spread in organised nature. In the vegetable kingdom, the Salts of Lime everywhere exist in minute proportion, while in the animal kingdom these Salts accumulate so as to obtain a particular prominence, (*vide* Phosphorus.)

It is used to precipitate or test for Boracic, Phosphoric, Oxalic and Hydrofluoric Acids, which combine with its Calcium or Lime.

Phosphate and Borate of Lime are soluble in Acetic Acid, whilst Oxalate of Lime and Fluoride of Calcium are insoluble. Oxalate of Lime is soluble in dilute Hydrochloric Acid, in which liquid Fluoride of Calcium is insoluble.

It may be used to detect the Alkaline Carbonates, which produce with it Carbonate of Lime.

It is used to strengthen Alcohol, which parts with its water with difficulty. One part of perfectly dry (calcined) Chloride of Calcium is distilled by a gentle heat with three of Alcohol, and thus about ⅔ of the spirit are obtained perfectly pure.

It detects in vegetable substances the Oxalic, Malic and Tartareous Acid, with which it produces a white crystalline precipitate, highly insoluble in water, but readily soluble in dilute Nitric Acid.

94.—Having considered the nature and properties of the various re-agents, it may be as well to devote a few pages to the consideration of the substances which come under their operation as before enumerated. First of the Gases.

These are :—

GASES AND NON-METALLIC SOLIDS.—*Oxygen, Hydrogen, Nitrogen, Chlorine, Bromine, Iodine, Fluorine, Boracic Acid, Hydrocyanic Acid, Sulphuretted Hydrogen, Silicon, Carbon, Sulphur and Phosphorus.*

EARTHS—*Baryta, Strontia, Lime, Magnesia, Alumina.*

METALS—*Manganese, Zinc, Iron, Tin, Cadmium, Gold, Arsenic, Antimony, Nickel, Cobalt, Bismuth, Copper, Lead, Mercury, Silver, Platinum.*

95.—OXYGEN—Dephlogisticated Air.—(*O.*)

There is so much to be said, and so much to be understood, by the student of Chemistry regarding this and the two following gases, particularly Hydrogen and Nitrogen, that it will be necessary to refer the reader to some Encyclopedia or Book of Instruction on Chemistry, for the details of their qualities and uses.

Oxygen is one of the ingredients of the atmosphere, which consists in the main of 21 Oxygen, 79 Nitrogen, and a small quantity (.0004) of Carbonic Acid. It is the great supporter of life and of combustion, but unless diluted it would destroy the life of both plants and animals by its excessive stimulus. It combines with every combustible body, with all the metals (forming Oxides) and with the greater number of vegetable and animal substances. It constitutes $\frac{8}{9}$ of the whole weight of sea water, (in which also it is found constituting part of the air mixed up with it, in the proportion of 32 per cent., the proportion in the atmosphere being as above stated 21 only,) and not far from half the weight of the common crust of the earth.

Plants, trees, &c., decompose the air, absorbing its carbon (from the Carbonic Acid) and Hydrogen, and disengaging the Oxygen in a state of purity. Light (and connected with it electricity) favors this decomposition greatly, and at night during its absence the action of vegetation is alternated or reversed, and Carbonic Acid being given out and Oxygen absorbed, they are unhealthy, especially in closed rooms.

In the Animal Kingdom it forms something less than the fourth part of the weight of dried muscular flesh, and half of the weight of lignine or wood.

There are but few bodies which do not contain Oxygen; such are Carbon as in the Diamond, Sulphur in some of its states, such metals as are found in the virgin state, the combinations of Metallic bodies with Chlorine, Iodine, and Sulphur as the beds of Rock Salt, and the Sulphurets of Iron, Copper, and Zinc.

Oxygen Gas is obtained chiefly from the black Oxide of Manganese with the aid of heat, and a little, about its own weight, of Sulphuric Acid.—One pound of the best Manganese yields upwards of 1400 cubic inches of Oxygen Gas nearly pure.

A mixture of one Oxygen and two Hydrogen by volume, yields by explosion, water, or by weight eight oxygen to one Hydrogen. Hence their equivalents 8 and 1.

96.—HYDROGEN—Inflammable Air.—(*H.*)—

As its name expresses, is one of the constituent elements of water, of which it forms $\frac{1}{9}$ part by weight, or 11 per cent. It is an essential constituent of some minerals, as Coal and Sal-Ammoniac, in which it does not exist as an element of water. It is evolved from Volcanoes or from fissures in the Earth in combination with Carbon, Sulphur, Chlorine or Nitrogen, under the forms of light Carburetted Hydrogen, Sulphuretted Hydrogen, Hydrochloric Acid and Ammonia.

It makes up about $\frac{1}{16}$ part of the whole weight in the tissue of wood, and nearly the same in starch and sugar, and of dried muscular flesh it forms about $\frac{1}{15}$ by weight.

It is an essential constituent of all organized beings, animal and vegetable, either combined with Oxygen to form water or otherwise. It is one of the ingredients in the varieties of bitumen, oils, fat, ardent spirit, ether, &c.

It is impossible to procure liquid; It is the lightest substance whose weight we are able to estimate, being about 14 times lighter than atmospheric air. It is not fitted for respiration. It burns when pure with a yellowish lambent flame, but all burning substances are immediately extinguished when immersed in it. It is, therefore, incapable of supporting combustion.

It is usually prepared from Sulphuric Acid and Iron or Zinc filings. Acid, dilute with four or five times its weight of water, is poured on Iron filings or bits of Zinc. When the Acid comes in contact with the metal, violent effervescence takes place, and the Hydrogen is liberated without the application of heat, the Oxygen combining with the metal.

97.—NITROGEN—Phlogiston, Azote.—(*N.*)

It exists sparingly in the Mineral Kingdom, has not been found in non-fossiliferous rocks, and is not contained, like Oxygen, in the common rocks of the crust of the Earth. It is a constituent of Coal, of the Nitrates of Ammonia ($N\,H_4\ O$) and of some mineral waters. It forms 79 per cent. of atmospheric air.

As a constituent of Ammonia, it enters largely into the composition of all vegetable organization, and is particularly abundant in the Cruciferæ and Fungi. It enters into the composition of most animal substances as Albumen, Fibrine, Gelatine, Mucus, Uric Acids, &c.

It is a colorless, odorless, tasteless, Gas, neither combustible nor is it a supporter of combustion or of life. It neither reddens Litmus paper nor whitens Lime water.

The readiest way of obtaining Nitrogen is to burn a piece of Phosphorus in a confined portion of atmospheric air. The Phosphorus combines with the Oxygen of the air, and the residual Gas, after being thoroughly washed, is nearly pure Nitrogen.

Besides Air there are five compounds of Oxygen and Nitrogen, *viz.* the Protoxide, Deutoxide, Hyponitrous Acid, Nitrous Acid and Nitric Acid.

98.—CHLORINE—(*Cl.*)—

In the Inorganic Kingdom exists principally in combination with Sodium, either dissolved in the water of the Ocean or forming deposits of Rock Salt. It also occurs native in combination with Magnesium, Calcium, Lead, Silver. Free Hydrochloric Acid is met with in the neighbourhood of volcanoes, probably produced by the decomposition of some Chloride.

In the Organic Kingdom it is found in combination in both animals and vegetables, but it does not possess acid properties, and does not redden the blue vegetable colors. In the former as Hydrochloric Acid, it forms an essential part of the digestive powers. Sprengel says maritime plants exhale Chlorine during the night.

It is a yellowish green colored Gas, with an astringent taste and disagreeable odor, and is one of the most suffocating of the Gases. It is a supporter of combustion; several of the Metals, as Tin, Copper, Arsenic, Zinc and Antimony, when introduced into Chlorine in the state of powder or in fine leaves, are suddenly inflamed. In all these cases the combustible substances unite with Chlorine.

The solution which is made by transmitting a current of Chlorine Gas through cold water has the color, taste, and most of the other properties of the Gas itself; 1 vol. of water dissolves 3 vols. of Chlorine.

Chlorine Gas unites with water by seizing the Hydrogen to form Hydrochloric Acid and liberating the Oxygen. This change takes place quickly in sunshine, more slowly in diffused daylight, and not at all when light is wholly excluded. Hence the necessity of keeping moist Chlorine Gas, or its solution, in a dark place, if it is wished to preserve it for any time.

Chlorine may be prepared from Peroxide of Manganese, and Hydrochloric Acid by mixing the latter (concentrated) with half its weight of the former finely powdered; a moderate heat assists the effervescence and evolution of the Chlorine Gas. It should be collected in inverted glass bottles filled with warm water, and when the water is wholly displaced by the Gas, the bottles should be closed by a well-ground glass

stopper, as some Muriatic Acid Gas commonly passes over with it, the Chlorine should not be considered quite pure till after being transmitted through water.

When Chlorine water and some other body, which has a strong affinity for Oxygen, are presented to one another, water is usually resolved into its elements, its Hydrogen attaching itself to the Chlorine and its Oxygen to the other body. Hence it happens that Chlorine is indirectly one of the most powerful of oxidizing agents.

One of the most important properties of Chlorine is its bleaching power. All animal and vegetable colors are speedily removed by Chlorine, and when the color is once discharged it can never be restored; water must be present however during bleaching.

Chlorine is likewise useful for the purposes of fumigation. It has the power of destroying the volatile principles given off by putrefying animal matter, and it probably acts in a similar way on contagious effluvia.

Whenever free Chlorine exists in materials under examination, it may be detected by its decolorizing effect upon Litmus, and when such substances are distilled with water, and the vapor is made to pass over paper impregnated with Starch and Iodide of Potassium, a beautiful blue color is produced, which disappears with excess of Chlorine.

CHLORIC ACID.—($Cl.\ O_5$.)

This Acid, in its concentrated state, appears in the form of a yellow oily liquid, the odor of which resembles that of Nitric Acid.

All the Chlorates are soluble in water. They are decomposed upon ignition, Oxygen Gas being given off, and a Metallic Chloride left.

When heated along with Organic substances, they deflagrate with far greater violence than the Nitrates.

To detect this Acid, add to a small quantity of the solid substance under examination a few drops of concentrated Sulphuric Acid in the cold. The Chlorate (say of Potash) will be decomposed. Sulphate of Potash and Perchlorate of Potash ($KO,\ Cl.\ O_7$) being formed along with a greenish yellow colored Gas (Chlorous Acid, $Cl.\ O_4$) which escapes. The application of heat must be avoided, and the quantities operated upon should be small, to prevent any loud and violent explosion taking place.

99.—BROMINE AND HYDROBROMIC ACID.—(*Br, and HBr.*)—

So called from its unpleasant smell (Bromas, fœtor), is found in both kingdoms, but never free. It exists in sea water, combined with Magnesium and Sodium, and mineral waters, and in Marine plants and some Marine animals.

Bromine is usually procured from Bittern (the liquor of sea water from which Chloride of Sodium has been separated by crystallization.) The method is similar to that of detecting it in any other liquid compound, *viz.*, pass Chlorine Gas through the solution, or add an aqueous solution of that Gas; the Bromine being set free, will communicate a yellowish red tint to the liquid, except the quantity be very minute. If the solution be now agitated with Ether, it will remove all the Bromine from the liquid, dissolving it and forming a yellow colored solution. If the Etherial solution be agitated with Potash, the color will disappear, Bromide of Potassium and Bromate of Potash being formed. By evaporating this solution to dryness and igniting the residue, the Bromate of Potash will be converted into Bromide of Potassium. On heating the Bromide along with Peroxide of Manganese and Sulphuric Acid in a small retort, *yellowish red vapors* will be evolved, unless the quantity be very minute. These vapors when brought in contact with Starch paste, will communicate to it an orange yellow color, which disappears on exposure to the air.

Bromine is a deep red liquid when seen in mass by reflected light, Hyacinth red by transmitted light through thin layers. Its taste is acrid and somewhat aromatic, like Saffron. It boils at 117° F., and its vapor rises visibly even at common temperatures. It is soluble very slightly only in water, more so in Alcohol, and much more so in Sulphuric Ether, also in Sulphuret of Carbon, which it colors purple; and these liquids remove it from water. At 4° below Zero F. it congeals into a brittle solid. It bleaches and destroys vegetable colors. It is fatal to animal life, one drop being sufficient to kill a small bird. It destroys vegetable blue colors, converting them to yellow, and colors solution of starch yellow. It precipitates Nitrate of Silver, producing a yellowish Bromide, which is more soluble in Ammonia than Iodide of Silver.

Bromine and Bromides, melted with Salt of Phosphorus and Oxide of Copper (*see* Iodine) impart to the blowpipe flame a greenish blue color. Heated with Bi-sulphate of Potash in the closed tube they yield vapors of Bromine, which are recognized by their yellow color and peculiar smell.

If the Bromine is combined, it may be set free by heating the compound with Bisulphate of Potash. If it be desired to prove its presence in more solid organic or animal matter, it may be boiled with Potash, which forms Bromide of Potassium, in which it may be recognized by means of Nitrate of Silver, or the Bromine may be set free by a current or solution of Chlorine being passed into the solution.

Antimony or Arsenic, takes fire when dropped into liquid Bromine. When Potassium or Phosphorus is dropped in, a violent explosion takes place.

The soluble Bromides cause white precipitates with the Nitrate of Silver, Acetate of Lead and Protonitrate of Mercury. Bromide of Silver is yellowish white, clotty, insoluble in a weak solution of Ammonia (thus differing from Chloride of Silver), but dissolves in a concentrated solution. If a few drops of a solution of Chlorine be added to a solution of Bromide, and then a little Sulphuric Ether, we obtain an Ethereal solution of Bromine, of a Hyacinth red color, which floats on the water.

HYDROBROMIC ACID—This acid resembles very closely in its properties Hydrochloric Acid Gas.

It is decomposed by Chlorine, Bromine being set free, and Hydrochloric Acid formed.

It is composed of equal volumes of Hydrogen and Bromine.

100.—IODINE AND HYDRIODIC ACID.—*From Iōdes, violet colored.*—*(I.)*

In the Inorganic Kingdom it has been found in Ores of Zinc and Lead, in the sea water (where it probably exists as an Iodide of Sodium or Magnesia); in mineral waters, also in Rock Salt.

In the Organic Kingdom it is found in many marine animals, (molluscs,) in cod liver oil and in numerous vegetables, particularly Fucoids. It is from these that it is obtained, that is from their ashes or kelp.

Iodine is a crystallizable solid, its primary form being a rhombic octahedron. It is usually met with in micaceous soft friable scales, having a greyish black color, a metallic lustre, an acrid hot taste, and a disagreeable odor, somewhat similar to that of Chlorine. Iodine vapor has a beautiful violet color. In odor and power of destroying vegetable colors it resembles very dilute aqueous Chlorine. It dissolves in 7000 parts of water. The solution is of an orange yellow color, and in small quantity tinges raw starch of a purple hue. Boiling water aids its sublimation. It is very soluble in Alcohol and Ether.

If Salt of Phosphorus be melted with as much Oxide of Copper as suffices to make a very dark green bead, and with this, Iodine, or an Iodide, be fused in the blowpipe flame, they will impart to it a very beautiful and intense green; and when heated in the closed tube with Bisulphate of Potash, they yield violet vapor. In solution, Iodine gives a precipitate with Nitrate of Silver like that of Chlorine, which however is soluble with difficulty in Ammonia.

Iodine in a *free* state, forms with Starch, even in highly dilute solutions, a purple precipitate of Iodide of Starch, but if the Iodine is in a

state of combination with Hydrogen, or any metal, it is necessary to liberate it before applying the Starch test.

This is done by Nitric Acid, which liberates Iodine from its Hydrogen and Metallic compounds, Nitric Oxide being given off. The liberated Iodine communicates a brownish yellow tint to the solution, and if it is concentrated a portion of the Iodine separates as a black precipitate. When solid Iodides are heated with Nitric Acid, the Iodide sublimes in the form of violet colored vapors, which condense upon the colder parts of the vessel as a blackish sublimate.

If Nitric Acid be added to a solution containing Iodine, and subsequently thin Starch paste, the fluid will acquire a blue or blackish blue tint owing to the formation of Iodide of Starch.

If Iodine is to be obtained from animal matters, they must be boiled in water and a little solution of Potash added, by which operation Iodide of Potassium and a little Iodate of Potash are formed, and may be recognized by means of Nitric Acid and Starch.

Sulphuric Acid, Binoxide of Barium and Chlorine also liberate Iodine from its combinations. If the latter be added in excess they combine together, forming a colorless compound (Chloride of Iodine.)

HYDRIODIC ACID—(*HI*)—This Acid and its compounds resemble in their properties the corresponding compounds of Chlorine and Bromine. Many of the Iodides of the heavy metals are more insoluble in water than the corresponding Chlorides.

If Sulphuretted Hydrogen be passed through a mixture of water and Iodine, and the liquid obtained be heated, the excess of Sulphur flies off and leaves liquid Hydiodic Acid. Hydriodic Acid may also be obtained by passing Hydrogen over Iodine at an elevated temperature.

101.—FLUORINE (*F*) AND HYDROFLUORIC ACID—(*HF.*)

Fluorine exists combined with Lime in the bones and teeth of animals. It has been found also in the Vegetable Kingdom to a sufficient extent to account for its existence in the Animal Kingdom. In the Mineral Kingdom it exists in great abundance.

It is supposed to exist (not having been obtained in a separate state) in Fluor or Derbyshire Spar. If some of this mineral be powdered and distilled with strong Sulphuric Acid from a leaden retort into a leaden receiver kept cold with ice, an intensely active fluid is produced, which instantly blisters the skin, and has the power of etching glass as well as dissolving Silica. For the mere purpose of observing its etching power on glass, a piece of sheet lead bent up at the edges will be sufficient to contain a paste made from the Spar and Acid.

From this, held over the lamp, dense white fumes will be disengaged, which, if a plate of glass spread with a thin coating of bees' wax and engraved with any figures be held over it for 5 or 10 minutes, will have the effect of etching it, as may be seen by subsequently removing the wax with turpentine.

When the distilled fluid above-mentioned is dropped into water, a hissing noise is produced, with much heat, and an acid fluid is formed.

HYDROFLUORIC ACID—(*HF.*)—This Acid, from its properties, cannot be prepared or kept in glass bottles.

Fluorine cannot be detected in a compound, when Silica is present, because they combine, Fluoride of Silicon ($Si\ F_2$) and water being formed. Should the compound contain therefore Silicic Acid as well as Fluorine, Fluoride of Silicon, and not Hydrofluoric Acid, will be disengaged by the Sulphuric Acid.

To detect, therefore, Fluorine when Silica is present, the compound must be powdered and mixed with strong Sulphuric Acid in any dry tube; If the evolved Gas be transmitted through a tube moistened within with water, the inner surface will become coated with a deposit of Silicic Acid, which will render the tube less transparent. This deposit is occasioned by the decomposition which Fluoride of Silicon undergoes in the presence of water, *viz.*, into Silica and Hydrofluosilicic Acid ($3\ HF\ 2\ SiF_3$).

If a Fluoride mixed with Bisulphate of Potash is heated in a test tube, Hydrofluoric Acid is disengaged, which is easily detected by the etching of the glass.

When Fluorine is present in small quantities, and not as an essential constituent, if the assay be heated alone in the closed tube having a strip of Brazil wood paper in its mouth, the glass will be corroded, and the paper become yellow. But when the Fluorine is in large quantity, and is chemically combined, the assay must be heated with fused Salt of Phosphorus in the open tube in order to produce the same results.

102.—BORACIC ACID.—(BO_3.)—

Occurs native in the Volcanic formations of the Lipari Islands, where it is evolved together with Hydrosulphuric Acid. It is also dissolved in hot springs there, and at Sasso, in Tuscany, whence its mineralogical name of Sassoline.

To detect Boracic Acid, the assay is heated with Sulphuric Acid, and evaporated to dryness; Alcohol is then added and set on fire. The Boracic Acid, if present, is volatilized with the Alcohol, and imparts a decided green color to the flame.

This Acid is best obtained by adding to a boiling concentrated solution of Borax (Biborate of Soda) strong Sulphuric Acid until the liquor becomes sour to the taste; on cooling, the greater part of the Boracic Acid separates from the solution, in the form of colorless crystalline scales containing water. When ignited they fuse to an anhydrous glassy mass, which, on exposure to the air, absorbs water, swells, and becomes opaque. The Hydrated Acid is much more soluble in hot than in cold water. When an Alcoholic or aqueous solution of this Acid is evaporated, a portion of the Acid volatilizes with the vapors of the solvent, but alone it is perfectly fixed at a red heat. One peculiar property which this Acid possesses is that of affecting Turmeric paper in the manner of a free Alkali: it acts however upon blue Litmus paper like other Acids. All the Borates, with the exception of the Alkaline ones, are almost totally insoluble in pure water; they dissolve readily in Acids, and in water containing Ammoniacal Salts. They are not decomposed upon ignition; they are colorless, and all of them, even the Acid Salts, manifest an Alkaline reaction.

By the aid of Borax, Potash and Soda may be recognized in mineral substances, by first fusing the substance with twice its weight of Borax, then dissolving in dilute Nitric Acid, concentrating the solution to separate the Silex. Boiling with Carbonate of Ammonia then separates the earthy and metallic ingredients. The liquid is then mixed with a sufficient quantity of Nitric Acid, and evaporated till the whole of the Boracic Acid is separated.

Nothing now remains but the Nitric Acid combined with the Alkaline constituents of the mineral (and Ammonia), which may be distinguished by their appropriate tests, *viz.*, Tartaric Acid or Perchloride of Platinum, the Nitrate of Ammonia being first got rid of by exposure to a dull red heat.

At high temperatures Boracic Acid displaces the strongest of the other acids, and is exceedingly useful in fluxing out the baser metals from the nobler.

103.—HYDROCYANIC ACID—(HCy)—Prussic Acid.—

Is a product peculiar to the Vegetable Kingdom, being procured readily from bitter almonds, peach kernels, &c., &c. During the decomposition of animal matters, Cyanogen is frequently generated. Cyanogen Gas burns with a purple flame and destroys life on being breathed. When a few drops of Hydrocyanic Acid are poured on paper, a part evaporates so rapidly as to produce a degree of cold sufficient to crystallize the remainder. It is the only liquid which possesses

this property. It is the Hydrogen compound of the radical Cyanogen which is itself a compound of Carbon and Nitrogen ($C_2 N$). In its anhydrous state it is a colorless, volatile, inflammable liquid.

The compounds of Cyanogen, with the metals of the Alkalies and Alkaline earths, are soluble in water: their solutions possess an Alkaline re-action, and are decomposed with the liberation of Hydrocyanic Acid by the weakest Acid. If to a solution of free Hydrocyanic Acid or an Alkaline Cyanide, *Potash* and a mixture of a *Per* and *Protosalt of Iron* be added, a greenish-blue precipitate will be produced, which on the addition of Hydrochloric Acid will re-dissolve, Prussian blue precipitating.

104.—SULPHURETTED HYDROGEN—Hydrosulphuric Acid.—(HS) This Acid exists at the common temperature and pressure as a colorless inflammable Gas, possessing a highly offensive odor, resembling that of rotten eggs. It is soluble in water, three volumes of which dissolve one volume of the gas; this solution reddens Litmus paper, and on exposure to the air is decomposed, water being formed, and Sulphur in a highly divided state separated.

It is decomposed by Chlorine, Iodine, and Bromine, which separate its Hydrogen and cause the Sulphur to be deposited. It precipitates the Salts of Lead, black, those of Antimony, orange yellow, those of Arsenic, yellow, and those of Zinc, white, under the influence of Acetate of Soda.

Most Metallic Sulphides dissolve with decomposition in Hydrochloric Acid, in which case Sulphuretted Hydrogen is evolved, which, from its smell or from its blackening a piece of paper moistened with any soluble Salt of Lead, is easily recognized.

When Sulphides are dissolved in Nitric or Nitro-Hydrochloric Acid, Sulphuric Acid is formed along with a separation of Sulphur, which may be recognized by its color, and also its behaviour upon ignition. In the case of Sulphides, therefore, which, from their insolubility in Hydrochloric Acid, must be dissolved in Nitric or Nitro-Hydrochloric Acids, the Sulphur is converted into Sulphuric Acid and not given off as Sulphuretted Hydrogen.

When the Sulphides of the heavy Metals are heated in contact with air, Sulphurous Acid is evolved, the Metal being left in some cases uncombined and in others as an Oxide. The Sulphides of the Alkalies and Alkaline earths are converted by this process into Sulphates.

Sulphuretted Hydrogen, if present in Gas or elsewhere to the amount of $\frac{1}{20000}$ part, may be at once detected by presenting to the

vapor, while it is still wet, a piece of paper moistened with Sugar of Lead (Acetate of Lead) which will become browned or blackened.

Next of the *Non-Metallic Solids.*

105.—SILICON—(*Si*) Silicic Acid or Silica ($Si\ O_3$)—

Is the basis of almost all the scintillating stones, such as flint, rock crystal, quartz, agate, chalcedony, jasper, &c. It is deposited from some springs in a stalactitic form, as the Geysers in Iceland. It is also found in the tissue and structure of most plants, especially grasses and the equisetums.

De la Beche calculates that Silica alone constitutes 45 per cent. of the mineral crust of our Globe.

In the vegetable kingdom, Silica performs the important office of imparting strength to the stem as in grasses, so as to enable them to bear the weight of the grain. In the stem of the equisetaceæ, or horse-tails, it is seen to be disposed in a crystalline arrangement. In the Bamboo, deposits of pure Silica occur in considerable masses, to which the name of Tabasheer has been given.

The only Acid that dissolves Silica is the Hydrofluoric. In the state in which it is encountered by the analyst in every compound he examines, it is insoluble (in all but the above Acid), and is generally reduced by fusion with the carbonated alkalies. The fused mass or glass that results may be dissolved by plain water. On adding to the solution Hydrochloric Acid, this combines with the alkalies and bases also in the solution forming Chlorides, and the Silica is set free as hydrated Silicic Acid in a gelatinous form. The separation, however, of Silicic Acid from an aqueous solution of a Silicate on the addition of an Acid depends upon the amount of water present. If there is sufficient to dissolve it no separation takes place. The liquid should therefore be thoroughly *evaporated* to dryness. This, the *evaporation,* converts the Silica from the soluble to the insoluble form. Water is again added to dilute it, and the solution being filtered the gelatinous Silicic Acid (containing all or very nearly all the Silica in the compound) is left on the filter.

If Silica be merely precipitated, washed and dried by a moderate heat, it remains in the soluble condition, but if the same Silica be exposed to a red heat, it assumes the insoluble form; water no doubt is held with a force which may fairly be considered as an actual condition of combination, this is driven off by a red heat, and hence the difference.

The Alkaline Silicates are the only Salts of this Acid which are soluble in water.

On adding Chloride of Ammonium to a solution of an Alkaline Silicate, a gelatinous precipitate takes place.

Glass formerly made of Soda and Silica, is now generally made from Potash. Lead is used in flint glass and to give brilliancy to artificial gems.

Artificial stone is prepared by making a soluble glass first by dissolving broken flints in a solution of Caustic Alkali at 300° F. A properly prepared sand is mixed into a pasty mass with this solution, and pressed into the required forms. In a short time the mass hardens; heat is then applied to drive off the water, and the whole is converted into a very coherent sandstone.

The surface of many Oolite and Dolomite building stones, is decomposed and cracked off by the Carbonic Acid of the air combining with the Calcareous and Magnesian ingredients. It has been proposed to secure them by coating their surfaces with this soluble glass. The Carbonic Acid decomposing the Silicated Alkali, its Silica would be deposited on the surface as an insoluble glaze.

When Silicic Acid is fused with Carbonate of Soda before the blowpipe, a transparent colorless bead is formed, while Carbonic Acid is expelled. A small quantity of Soda ought only to be employed, as an opaque bead is produced when it is added in excess.

106.—CARBON—(*C.*)

Carbon exists in both kingdoms. To Lavoisier we are indebted for the discovery that, by combustion in Oxygen Gas, the Diamond and Charcoal yield the same product, Carbonic Acid gas. The Diamond has by some been supposed to be of vegetable origin, but Mr. Heuland found a specimen in primary rock. In India the sandstone is its matrix. It is remarkable that Carbon is rare among the older rocks.

Carbon in powder heated with Nitre deflagrates.

Plumbago and Anthracite consist principally of Carbon. Coal, Petroleum, Naptha also contain it.

In the Organic Kingdom it is an essential constituent of all organized beings, animal and vegetable.

Animal Charcoal prepared from bones is much used by chemists for purifying other substances. The theory of its decolorizing property is imperfectly understood. It is said to depend on some attraction between charcoal in very minute particles and coloring matter.

Wood Charcoal, though an excellent conductor of electricity, is a very bad conductor of heat, a property of considerable use on many occasions, as in lining crucibles. A remarkable property possessed by

it (in common with, but in a less degree than animal charcoal) is that of abstracting certain substances (such as Hydrosulphuric Acid, organic coloring principles, various odorous matters, &c.) from liquids in which they are dissolved, or through which they are diffused.

This property gives it its use as a filtering agent. Putrid water may thus be rendered sweet, particularly if aided by a few drops of Sulphuric Acid.

Common Vinegar boiled with Charcoal powder becomes perfectly limpid.

Saline solutions tinged yellow or brown, are rendered colorless, and afford perfectly white crystals.

The impure Carbonate of Ammonia obtained from bones, is deprived both of its color and fetid smell by sublimation with an equal weight of charcoal powder.

Another curious quality, is that of condensing within its pores a certain quantity of any Gas with which it may be placed in contact. This power appears to depend on capillary attraction. Beech wood charcoal (a cubic inch of which has about a hundred feet superficial of condensing surface,) will thus attract to itself 80 or 90 times its own volume of Ammoniacal Gas.

When Coal is deprived of its volatile parts by heating in close vessels, a peculiar kind of charcoal remains, called Coke. This is abundantly obtained as the residuum of the process for making Coal Gas, but not of the best kind for furnace purposes, owing to the complete abstraction of all its Hydrogen and inflammable Gas.

It is insoluble in water; hence the utility of charring the surface of wood exposed to that liquid, in order to preserve it, as in foundations, &c., below ground. It has attraction however for a certain portion of water, which it retains very forcibly.

Melted cast Iron is the only liquid which will dissolve Carbon. At a high temperature it is capable of dissolving a larger quantity than it can retain at a lower. As it cools, it gives out the excess in crystalline Laminæ, which are black and opaque, and of metallic lustre, and identical with Graphite.

Carbon combined with Iron forms Steel.

In Carbonate of Lime, one of the most abundant substances in nature, as chalk, marble, limestone, marl, Carbon forms $\frac{1}{7}$ part by weight. In dried muscular flesh the proportion of Carbon by weight is not far from $\frac{1}{2}$; and in the tissue of wood the weight of Carbon is nearly $\frac{3}{7}$.

The purest Carbon for chemical purposes, is obtained by strongly igniting lamp black in a covered crucible.

Charcoal has a powerful affinity for Oxygen, whence its use in blowpipe Analysis, in disoxygenating metallic Oxides, and restoring their base to its original metallic state, or reviving the metal. Thus too, it decomposes several of the Acids, as the Phosphoric and Sulphuric, from which it abstracts their Oxygen, and leaves the Phosphorus and Sulphur free.

CARBONIC ACID—(CO_2)—Fixed Air—

Is a constituent of the atmosphere in the proportion of ·0004 per Cent. It is thrown out in mines as choke damp, and exists in most mineral waters, rendering them sparkling. It is found (native) in combination with many mineral bases, especially Lime, as Marble, of which it composes 45 per Cent. by weight, or as De la Beche says 1 cubic yard of stone contains 16,000 cubic feet of Gas. It is produced in the burning of Coal, Wood, Charcoal, &c., and is the cause of the last of these being destructive of life. Although highly necessary in the Organic Kingdom to all vegetation, and universally absorbed by their leaves, it is yet exhaled by them also in the absence of light during the night, and in dark and shady places. Animals exhale it also during the process of respiration, and if the breath be passed by a tube through common Lime water, a precipitate of Carbonate of Lime will be formed. It is also produced during the fermentation of Saccharine fluids, the destructive distillation of animal substances, and the decomposition naturally of organic matter.

Carbonic Acid is usually made from Marble or Carbonate of Lime, and Hydrochloric Acid diluted with four or five times its volume of water. At the common temperature and pressure it exists as a colorless, inodorous, and non-inflammable Gas. Being heavier than the Atmosphere (as 1·52 to 1) it can be decanted from one vessel to another like a liquid. It reddens blue Litmus paper, which returns to its original color as the Acid volatilizes. It is soluble in cold water, but when the solution is heated the gas escapes.

The neutral Alkaline Carbonates are the only neutral Salts of this Acid which are soluble in pure water. All the Carbonates are decomposed in the presence of the other Acids (Hydrocyanic and Hydrosulphuric excepted) with evolution of Carbonic Acid.

To detect Carbonic Acid add to the solution or solid substance under examination, Hydrochloric Acid; should any Gas be evolved, allow it to accumulate by placing the thumb on the mouth of the test tube, and afterwards decant it (taking care not to allow any of the liquid to pass over along with it) into another test tube half filled with Lime water.

A white precipitate of *Carbonate of Lime* will be produced, if Carbonic Acid is present.

It may be collected and its quantity estimated by passing dry air containing it slowly through a glass tube, containing Hydrated or Caustic Potash, which absorbs more than 100 times its volume of Carbonic Acid; the increase in weight of the tube will show the amount of the Gas.

Or if the air to be tested be in a graduated glass tube, the lower or open end of which is immersed in Mercury, and into this be introduced about $\frac{1}{40}$ of the volume of air, of strong solution of Potash, the volume of the air immediately diminishes, the Carbonic Acid being absorbed by the Potash.

In a solid compound it may be estimated by using an apparatus similar to that figured for Sulphuretted Hydrogen. In one bottle is the solid in the other and smaller one Oil of Vitriol; and the whole is air-tight and carefully weighed. By suction at the last tube out of the small bottle, the air from the large one is abstracted, and Sulphuric Acid passes back in its place. This causes effervescence and the expulsion of the Carbonic Acid, which passing through the Oil of Vitriol is deprived of its moisture, and the difference in weight of the apparatus at the end of the operation gives the amount of Carbonic Acid.

Many of the insoluble Carbonates dissolve in water containing free Carbonic Acid, from which solutions they are precipitated on boiling, the free Acid being expelled. It is in this state that most of the Lime and Magnesia in spring and river waters exist. The incrustations which are formed in the vessels in which such waters are boiled, are due to the precipitation of these Carbonates, occasioned by the removal of the free Carbonic Acid. Carbonic Acid is best detected in waters by adding to them Lime water; by this means not only is the Carbonate of Lime which is formed precipitated, but also that which pre-existed in the solution. This process is employed on a large scale for softening hard waters (waters impregnated with earthy matters.)

All the Carbonates, with the exception of those of the Alkalies, lose their Acid upon ignition, the metal being left either in an Oxidized or uncombined state, according to its greater or less affinity for Oxygen. The Alkaline Carbonates and Bicarbonates affect test paper in the manner of a free Alkali.

The following precautions must be attended to in testing for this Acid. When the substance is in the solid state, a little water should

be added prior to the Acid, to displace the air in its pores, otherwise an apparent effervescence will ensue, which is due to the expulsion of common air. In the case of Alkaline Carbonates the decomposing Acid must be added in excess, otherwise the Carbonic Acid set free may combine with some of the undecomposed Carbonate, forming with it a Bicarbonate, and thus prevent any effervescence from taking place.

107.—SULPHUR—(*S.*)—

Is found imbedded in rocks (native Sulphur) or produced by sublimation (Volcanic Sulphur); Sulphurous Acid Gas rushes out from Volcanoes; Sulphuric Acid is found native, both free and combined. Hydrosulphuric Acid Gas is evolved from Sulphurous water, and the soil, in Italy and in other places.

In the Organic Kingdom it is found in Liliaceæ (as Garlic); in Cruciferæ (as Mustard); in Umbelliferæ (as Asafœtida), and in many other orders of plants. The Alkaline and earthy Sulphates are frequently met with in vegetables; Sulphur is also a constituent of some animal substances (as eggs, urine, &c.)

United to Iron, Sulphur forms Iron Pyrites; all the Ores called Pyrites are combinations of Sulphur with different Metals.

Sulphur is insoluble in water; but in small quantity in Alcohol and Ether and more largely in Oil. It combines readily with Chlorine.

Material suspected to contain Sulphur may be heated in a retort with some Acid, and the Gas which is disengaged being passed into a solution of Acetate (or Nitrate) of Lead, a black precipitate will be formed.

108.—PHOSPHORUS—(*P.*)

Various Phosphates are found native but in small quantities; those of Lime, Lead, Iron, Copper, Manganese may be mentioned as examples. Phosphate of Lime is a very important constituent of the organic exuviæ (Coprolites, &c.) entombed in the fossiliferous rocks.

The Organic Kingdom abounds with Phosphorus or its Acid. It is found in various vegetables. In animals it is found in almost every part of their bodies which is not volatile. There is not in all probability any part of these organized beings which is free from it. It has been obtained from blood; flesh, both of land and water animals; from cheese, and it exists in large quantities in bones, combined with calcareous earth, the Carbonate of Lime being in very inferior proportion to it. Urine contains it, not only in a free state, but also combined with Soda, Ammonia and Lime. In the shells of the crustacea, in egg shells and in coral, it has been found to be present also.

Some Limestone rocks in England (holding Coprolites) have as much as 18 per cent. of Phosphate of Lime.

It exists in the mineral kingdom, as Apatite and Phosphorite, which, though in some districts they constitute even mountain masses, yet are not widely spread over the earth's surface. Phosphorus exists in all fertile soils, and the source from which this important constituent of vegetable and animal substances originally reaches the soil, is now proved to be the mineral kingdom. Recent chemical analysis has satisfactorily shown, that minute portions of Phosphates are every where spread throughout the earth's surface, derived evidently from the constant degradation of rocks.

Even in sea water Phosphates have been detected.

In the Vegetable Kingdom, Phosphorus in minute proportions is spread throughout it. The ashes of Red Wheat contain, according to Liebig, 94 per cent, White Wheat 91, Pease 85, Beans 97 of Phosphates, whence it follows that the ashes of these several substances have Phosphorus present in them to the extent of 15 or 20 per cent., and as Phosphates are invariable constituents of the seeds, not only of all kinds of grasses and leguminous plants, but also of the seeds of plants in general which are fit for food, it is not too much to say that Phosphorus in minute proportions is spread throughout the Vegetable Kingdom.

Liebig has shown the very great importance of the Phosphates to agricultural crops and vegetation. He states that the "plant containing the most Alkaline Phosphates and earthy Salts, will produce more, or a greater weight of seeds than another, which in an equal time has absorbed less of them."

All substances containing free Phosphorus are luminous in the dark, and exhale a powerful odor of Garlic; and when placed upon hot bodies, they give off white fumes of Phosphoric Acid. But it may happen that the Phosphorus has been converted into Phosphorous or Hydrophosphoric Acid; these, when boiled in water, disengage Phosphuretted Hydrogen, which when inflamed burns and gives off dense white fumes of Phosphoric Acid.

If the combustion of Phosphorus take place within a large glass receiver, the smoke is condensed in the form of white flakes, which consist of Phosphoric Acid.

Phosphorus is soluble in oils, and communicates to them the property of appearing luminous in the dark. It is also dissolved in Alcohol and Ether, but more sparingly.

PHOSPHORIC ACID—(PO_5.)

Anhydrous or Glacial Phosphoric Acid (PO_5) appears under the form of white flakes, which rapidly absorb moisture from the air and deliquesce. When perfectly dry it sublimes in close vessels, but loses this property by the addition of water, in which circumstance it differs greatly from Boracic Acid, which is fixed when dry, but rises by the help of water.

The aqueous solution of Phosphoric Acid is a colorless and odorless liquid, possessing the usual characteristics of an Acid. When strongly heated in an open Platinum vessel, it volatilises without a residue.

The neutral Phosphates, with the exception of the Akaline ones, are nearly all insoluble in water.

If Phosphoric Acid be saturated with an Alkali (Soda), so as to form a soluble Phosphate, it may be distinguished from all other Acids by the following characters. It throws down with the soluble Salts of Lead, Lime and Baryta, white precipitates (Phosphates) soluble in Nitric Acid. With the Nitrate of Silver it causes a yellow precipitate, soluble in Nitric Acid and in Ammonia. Hydrosulphuric Acid causes no change of color or precipitate with it. If the soluble Phosphate be heated to redness, it is converted into a Pyrophosphate, which gives with the Nitrate of Silver a white precipitate (Pyrophosphate of Silver): saturated with Carbonate of Soda, no Phosphate insoluble in water should be thrown down.

According to Erdmann most of the combinations of Phosphoric Acid color the blowpipe flame green, especially when they have been moistened with Sulphuric Acid. The experiment must be made in the dark, and succeeds when the mineral contains only 3 per cent of Phosphoric Acid. When the percentage is larger, the assay is melted with Boracic Acid in the outer flame, a bit of very fine Iron wire inserted into the red-hot bead, and the whole exposed to the reducing flame; Phosphuret of Iron is formed, which, on breaking the bead after it has cooled, appears as an Iron black magnetic globule. This test can be depended on only when no Sulphur or Arsenious Acid or Metallic Oxide reducible by Iron is present.

In solution, Phosphoric Acid yields a white crystalline precipitate with Chloride of Magnesium, on adding Ammonia, which is soluble in Acids, but not in Sal-Ammoniac, and with Acetate of Lead a precipitate, which, when fused before the blowpipe, becomes crystalline on cooling.

109.—Thirdly, of the Metallic Bases.

The characters of the earths BARYTA, STRONTIA, and LIME may be given by the following Table :

No.	Tests added.	Salts of Barytes.	Salts of Lime.	Salts of Strontia.
1.	Potash, ...	White precipitate soluble in excess of water, ...	Gelatinous white precipitate, ...	White precipitate soluble in excess of water.
2.	Carbonated Alkalies,	White precipitate, ...	White precipitate, ...	White precipitate.
3.	Sulphuric Acid and Soluble Sulphates,	White precipitate insoluble in any known re-agent, ...	White precipitate if the solution is a concentrated one, ...	White precipitate, but no precipitate in a very dilute solution.
4.	Chromate of Potash,	Yellow precipitate soluble in an excess of Acid, ...	No effect, ...	No effect in a dilute solution.
5.	Phosphate of Soda,...	White precipitate soluble in Nitric Acid,..	White precipitate, ...	White precipitate.
6.	Sulphide of Ammonium, ...	No precipitate,	No precipitate,	No precipitate.
7.	Perchloric Acid, ...	Do., ...	Do., ...	Do.
8.	Ferro-cyanide of Potassium, ...	Do., ...	Do., ...	Do.
9.	Oxalic Acid and Oxalate of Ammonia,	Do.,...............	White precipitate insoluble in Acetic Acid, but soluble in Nitric Acid,	The Salts of Strontia are soluble in Alcohol, and the solution when inflamed burns with a beautiful red or purple color.

Carbonate of Baryta melts readily into a clear glass, which becomes milk white on cooling. Sulphate of Baryta (heavy Spar) is with difficulty fusible, but is reduced to Sulphide of Barium in the inner flame.

Carbonate of Strontia melts only on the thinnest edges, forming luminous excrescences. The Sulphate melts without much difficulty in the outer flame, and changes into Sulphide of Strontium in the inner flame. which, being dissolved in Hydrochloric Acid, dried and moistened with Alcohol and set on fire, imparts to the flame a beautiful red color. If Barytes and Strontia are both present in a mineral, they must be obtained in solution in Hydrochloric Acid, evaporated, ignited, pulverized, and digested in Alcohol, which dissolves Chloride of Strontium, but leaves Chloride of Barium undissolved. The solution of Chloride of Strontium in Alcohol burns with a carmine red flame. Sulphate of

Lime in the reducing flame becomes Sulphide of Calcium which has an Alkaline reaction.

As Baryta and Strontia yield a precipitate with Oxalic Acid, if they occur along with Lime, they must be previously separated by Sulphate of Potash.

Chloride of Calcium imparts a yellowish red color to the flame of Alcohol. (*See* Lime below.)

110.—MAGNESIA—(*Mg O*)—Talc Earth, Calcined Magnesia.

Magnesia, or the Oxide of Magnesium, exists much more sparingly than Lime in organic nature. Phosphate of Magnesia is a salt of continual recurrence in the chemical analysis of the parts of vegetables. Thus in the ashes of wheat, rye, beans and peas, the Phosphate of Magnesia exists to a considerable extent. It occurs also in the human blood and bones.

Magnesia differs so much from the other Alkaline earths, that its treatment is necessarily separate. In the first place it is not precipitated along with them by the general re-agent, Carbonate of Ammonia; and in the next, its Hydrate (or simple powder,) is soluble with difficulty, although its Sulphate, Epsom Salts, is readily soluble.

It re-acts as an Alkali when moistened with water on test papers. It is more soluble in cold than in hot water.

Magnesia is not precipitated either by Sulphuric Acid, Oxalic or Hydrofluosilicic Acid.

The Oxalate and Chromate, as well as some other Salts of Magnesia, are soluble in water. The soluble Magnesian Salts have a nauseous bitter taste; they do not alter vegetable colors when in a neutral state, and with the exception of Sulphate of Magnesia, they undergo decomposition when ignited. All the Salts of Magnesia, which are insoluble in water, dissolve readily in Hydrochloric Acid. Magnesia is found in the Mineral Kingdom, chiefly as Sulphate (Epsom Salts $Mg\ O, SO_3 + HO + 6\ Aq$) or Carbonate, and in combination with Silicic Acid in various proportions, forming the Meerschaum, Serpentine, &c.

A solution of Magnesia does not occasion any precipitate with the Ferro-cyanides, Hydrosulphurets, Oxalates or Bicarbonates. Magnesia is insoluble in Alkaline solutions, and is thereby distinguished from Alumina.

Ammonia precipitates from aqueous solutions of Salts of Magnesia a portion, as Hydrate ($Mg\ O, HO$). The rest of the Magnesia remains in solution with the Salt of Ammonia formed as a double Salt. The presence of Salts of Ammonia prevents the precipitation altogether.

The fixed Alkalies and the other Alkaline earths, precipitate Magnesia from its solutions in the form of Hydrate. This precipitate is soluble in Salts of Ammonia; the addition therefore of those substances,

either before or after the precipitation, prevents or re-dissolves the precipitate formed.

Arseniate of Ammonia ($3\ NH_4\ O,\ As\ O_5$) produces in solutions of Magnesia a white precipitate of Arseniate of Magnesia and Ammonia, ($2\ Mg\ O,\ NH_4\ O,\ As\ O_5$) which is soluble in Acetic and other weak Acids.

Phosphate of Soda precipitates it (which see)

If Magnesia or any of its compounds, after being ignited strongly by the blowpipe flame upon a charcoal support, be moistened with Nitrate of Cobalt, and again ignited, the mass assumes, on cooling, a pale flesh color.

111.—ALUMINA—($Al_2\ O_3$).

Alumina is very abundant in nature. It forms not only the basis of common clay, but is likewise a principal ingredient in many of the precious stones. Along with slight traces of Silica and Peroxide of Iron, it forms the Corundum, Sapphire and Ruby. As Hydrate it is known under the names of Diaspore and Gibbsite. Combined with Silica and Glucina, it forms the Emerald, Beryl, Euclase, and Chrysoberyl.

Alum is prepared from aluminous schist. The action of Alum on vegetable colors is that of an Acid. It is an Alumino Sulphate of Potash.

Alumina is thus recognized. The Ferro-cyanides, Oxalates and Hydrosulphuric Acid occasion no precipitate with it. Sulphide of Ammonium, the Caustic Alkalies and their Carbonates and Phosphate of Soda, throw down white precipitates. That produced by the Alkalies is soluble in an excess of Alkali, but is insoluble in solutions of the Carbonated Alkalies.

When pure it is white, but it frequently possesses a yellowish tint when obtained by drying the Hydrate. Its Salts are colorless, the soluble ones redden Litmus paper, and lose their Acids upon ignition. The Sulphide of Aluminum cannot exist in contact with water, being decomposed into Alumina and Hydrosulphuric Acid.

In solution it yields a white voluminous precipitate with Caustic Potash, which is easily and completely dissolved in excess of Potash, and again precipitated by Sal Ammoniac (Muriate of Ammonia). Carbonate of Ammonia also produces a precipitate, which it does not re-dissolve on being added in excess.

Alumina alone is quite unalterable before the blowpipe, but in many of its combinations may be detected by its blue color after being moistened with Protonitrate of Cobalt. If Alumina or its compounds be ignited upon charcoal by the blowpipe flame, afterwards moistened with a

few drops of Protonitrate of Cobalt, and again strongly heated, the mass assumes a *blue* color on cooling, which is characteristic of Alumina.

Lastly, of the *Metals.*

112.—MANGANESE—(*Mn.*)—

Occurs chiefly in nature as the Peroxide, but as this and its other forms are reduced to the state of Protoxide by Hydrosulphuric Acid, or any other reducing agent, the latter is the one treated of in Analysis.

It is found in the analysis of various woods, and also in the human hair.

When mixed with common Salt and Sulphuric Acid, it gives out Chlorine Gas.

Heated with Sulphuric Acid, it evolves Oxygen and forms a Sulphate of the Protoxide of Manganese. It is infusible before the blowpipe; dissolves in fused Borax with effervescence, and colors the globule of an Amethystine color, when no other metal is present capable of coloring the assay.

Protoxide of Manganese is of a greenish grey color, and its Hydrate is white. Both however turn brown when exposed to the air, being converted into higher Oxides. Its Salts are of a pale rose color and are decomposed by heat.

The white Hydrate may be precipitated from solution of the Protoxide by Caustic Potash or Ammonia. It gradually becomes dark brown on exposure to the air, and is insoluble in Carbonate of Ammonia.

The smallest quantity of Manganese can be detected in any of its compounds by fusing them in conjunction with Carbonate of Soda, and a small quantity of Nitrate of Potash upon Platinum wire, in the outer blowpipe flame, Manganate of Soda (NaO, MnO_3), which is of a bluish green color, being produced.

113.—ZINC—(*Zn.*)—

Is used to form Brass with Copper. It is soluble in dilute Sulphuric Acid with the evolution of Hydrogen Gas.

Oxide of Zinc is white, but becomes yellow on being heated, regaining its original color on cooling. The Salts of Zinc are colorless and are not precipitated by any Metal. The soluble ones redden Litmus paper and are decomposed by heat. The principal minerals of this Metal are the Anhydrous Carbonate (Calamine) ZnO, CO_2 and the Sulphide (Zinc Blende) ZnS.

When compounds of Zinc mixed with Carbonate of Soda, are subjected upon a charcoal support to the inner blowpipe flame, metallic Zinc is produced, which volatilizes, and on passing through the oxidizing

flame, becomes again converted into Oxide. The charcoal support becomes incrusted with this Oxide, which is of a yellow color while hot, and turns white on cooling.

If a compound of Zinc be moistened with Protonitrate of Cobalt and exposed to the outer blowpipe flame, a mass of beautiful green color will be produced.

Zinc Ores are not easily recognized from their appearance.

Silicious Oxide of Zinc gives a jelly with acids, but Calamine (the Carbonate) is dissolved with effervescence, and does not produce a gelatinous solution.

Zinc is not fit for drinking or cooling vessels, as its Salts are poisonous.

In commerce it is known by the name of "Spelter."

When the quantity of Zinc in an assay under the blowpipe is large, the flame assumes a bluish green color. Its yellow incrustation moistened with Protonitrate of Cobalt, becomes green when ignited, and cannot be volatilized in the inner flame.

Nos.	Tests for ZINC.	Precipitate.
1	Potash, Soda and Ammonia,... ...	White, gelatinous, soluble in an excess of the test.
2	Carbonates of Potash and Soda, ...	White, gelatinous, insoluble in an excess of the test. Soluble in Potash.
3	Carbonate of Ammonia,...	White, soluble in excess of the test.
4	Oxalic Acid and the soluble Oxalates, ...	White, Crystalline, soluble in Potash.
5	Ferro-cyanide of Potassium,... ...	White, insoluble in acid. It has a bluish tint if the solution is very acid.
6	Ferri-cyanide of Potassium,... ...	Yellow Salt, soluble in Hydrochloric Acid.
7	Hydrosulphuric Acid, ...	None with the Salts of the Mineral Acids. White with the Acetates.
8	Soluble Sulphurets, ...	White unless the solution is acid, in which case there is no precipitate.

114.—IRON—(*Fe.*)

Few minerals are free from Iron. It occurs also in the ashes of most plants, and in the blood and some other parts of animals.

Iron appears to possess important offices in organic nature. Its Oxide exists combined with Phosphoric Acid in such seeds as wheat, rye, and peas, and the Oxide is discoverable in the ashes of various kinds of wood, for example, in the ashes of firewood to the extent of 22.3 per cent. In the Animal Kingdom, Iron is an universal constituent of the blood.

It readily dissolves in dilute Sulphuric Acid with the evolution of Hydrogen Gas. The solution contains the Protosulphate of Iron, and

produces on the addition of Caustic Potash or Soda, a greenish white precipitate, (the hydrated Protoxide). This precipitate, by exposure to the air, attracts Oxygen, and is converted into the red or Sesqui or Peroxide.

The color of the Protoxide is black. Its Hydrate is white. The salts of the Protoxide are green, but their solutions exhibit this color only when very concentrated. They turn blue Litmus paper red, and are decomposed at a red heat. When dissolved, they absorb Oxygen from the air, the Oxide being thereby converted into Peroxide, which, in a neutral solution, is deposited as a yellow Basic Salt. Oxidizing agents, such as Chlorine and Nitric Acid, effect this conversion more speedily.

Peroxide of Iron, or Hematite, is of a brownish red color, and is well known as rust of Iron. Its Salts usually possess a reddish yellow color. The soluble neutral Salts of Mineral Acids, redden Litmus paper, and are decomposed by heat.

Nos.	Tests for IRON.	Protoxide Salts, Taste, Astringent; Metallic Color, Emerald Green.	Peroxide Salts, Color, Yellow or Red. They redden Litmus.
1	Potash or Soda, ...	Greenish white precipitate, becoming green, and ultimately dirty yellow when exposed to the air,...	Reddish brown precipitate, insoluble in an excess of the re-agent.
2	Ammonia, ...	Greenish white precipitate, soluble in an excess of the test,...	Ditto.
3	Alkaline Carbonates, and Phosphates, ...	White precipitate, becoming green in the air, ...	A brown precipitate. If a Carbonate is used, Carbonic Acid Gas is disengaged.
	(Carbonate of Lime gives no precipitate—Phillips.)		
4	Ferro-cyanide of Potassium,...	White precipitate, which becomes gradually blue in the air, and immediately under the influence of Chlorine, ...	Precipitate of Prussian Blue.
5	Ferri-cyanide of Potassium, ...	Deep blue precipitate,	No precipitate.
6	Hydrosulphuric Acid,..	No precipitate, ...	Milky white precipitate of Sulphur, and the Salt is reduced to the state of Protoxide.
7	Alkaline Sulphurets,...	Black precipitate, ...	Black precipitate.
8	Chloride of Gold, ...	Brown precipitate of metallic gold,... ...	No effect.

The most useful of the numerous Iron Ores is the Clay Iron-stone, which is found in the carboniferous formation, but also occurs between

that and the Chalk, and sometimes, but more rarely, in tertiary sedimentary deposits above Chalk; several parallel strata, from ½″ to 16″ thick are usually found together.

It also occurs in nodules in Clay Strata, and is evidently not of igneous origin, but deposited by water.

If masses of Clay, mixed with ground flints, be allowed to stand for some time unused, it often happens that the particles of powdered flint separate from the clay into detached hard stony nodules; so Clay Iron-stone appears to be formed in nodules by a chemical aggregation of the metal itself, diffused in suspension through a clayey medium. Minerals, containing Iron, form with Borax in the outer flame, a dark red glass, which, on cooling, becomes bright yellow, and in the inner flame, an olive green or mountain green glass, especially when Tin is added. Exceptions occur when Cobalt, Copper, Nickel, Chrome, or Uranium are present. When the Iron is combined with Sulphur or Arsenic, the assay must be previously roasted.

115.—TIN—(*Sn*)—

Occurs in the Mineral Kingdom only, and in two states; as an Oxide (the Tin-stone of which Stream Tin is a variety, and Wood Tin of mineralogists) and as a Sulphuret (Tin Pyrites).

Tin is always found in the primary rocks, never in any of later age, except when having been washed away it is found as Stream Tin in alluvial gravel. It is very sparingly found, chiefly in Great Britain and the Indian Archipelago. In Cornwall it exists in veins with Quartz at the junction of Granite and Primary Slate, and in Porphyry or Elvan Dykes. In the Malay Peninsula and Island of Banca, it is chiefly as Stream Tin.

In its massive form it is a yellowish white metal, having a peculiar odor when rubbed or handled. Tin may be reduced to powder by pouring melted Tin into an iron mortar, and rubbing until it is cold; or by shaking melted Tin in a wooden box, the inside of which has been rubbed with Chalk. In this state it constitutes powdered or granulated Tin.

The Oxide of Tin (SnO) is black, its hydrate being white. Nitric Acid and Nitrates in a state of fusion convert it into the Peroxide. The Protosalts of Tin are colorless, and are decomposed by heat. The soluble neutral Salts redden Litmus paper, and are decomposed in the presence of much water into soluble Acid and insoluble Basic Salts. The addition of water therefore to the Protosalts of Tin, produces a milkiness which disappears on the addition of Hydrochloric Acid. Sulphide of Tin (SnS) is of a dark brown color.

The Peroxide is of a light straw color; its hydrate is white. Nitric Acid converts metallic Tin and its Protoxide into the hydrated Peroxide, which is deposited in the form of a white powder. A Peroxide of Tin is likewise precipitated from Persalts of Tin on the addition of Caustic Soda to their solutions. These hydrates, although they have the same composition, are perfectly distinct in their chemical properties. The one formed by the action of Nitric Acid is insoluble both in Acids and the fixed Alkalies, the other is soluble in these re-agents. These modifications are capable of being transformed into each other. The insoluble one is rendered soluble by fusion with the Carbonated Alkalies; the soluble is converted into the insoluble form by ignition, Bisulphide of Tin (SnS_2) is of a yellow color.

If Per or Proto compounds of Tin, be mixed with equal parts of Carbonate of Soda and Cyanide of Potassium, and the mixed mass be subjected upon a charcoal support to the inner blowpipe flame, ductile metallic grains of Tin will be obtained unaccompanied by any incrustation upon the Charcoal.

Nos.	Tests for TIN.	Salts of Protoxide.	Bisalts of Tin.
1	Potash, ...	White precipitate soluble in an excess of the test, ...	Gelatinous white precipitate, soluble in excess of the test.
2	Ammonia, ...	White precipitate, insoluble in excess of the test, ...	White precipate, soluble in excess of the test.
3	Carbonate of Potash,	White precipitate with disengagement of Carbonic Acid Gas.	White precipitate with disengagement of Carbonic Acid Gas.
4	Ferro-cyanide of Potassium, ...	White gelatinous precipitate, ...	White gelatinous precipitate.
5	Ferri-cyanide ditto, ...	White precipitate, ...	No precipitate.
6	Hydrosulphuric Acid,.	Brown (black) precipitate, ...	Yellow precipitate soluble in Ammonia, but without loss of color.
7	Soluble Sulphurets,...	White precipitate, soluble in an excess of the test, ...	Yellow precipitate, soluble in an excess of the test.
8	Chloride of Gold, ...	Precipitate of purple of Cassius, ...	No precipitate.
9	Sheet of Zinc, ...	Precipitate of metallic Tin, ...	Metallic Tin.

Tin being very little attacked by articles of food and drink, and not forming poisonous compounds, like Lead and Copper, is much used for plates, cups, &c., and for tinning Copper and Iron vessels, which is done by heating them, rubbing with Sal-Ammoniac the inside, and then pouring in and spreading the melted Tin.

Tin occurs as an important ingredient only in Tin Pyrites and Tin Ores. It may be known by the white deposit of Oxide of Tin formed close behind the assay, which cannot be driven off, either in the outer or inner flame; moistened with solution of Cobalt, this deposit assumes a bluish green color, which is however very different from that of Oxide of Zinc. This Oxide can be reduced by Soda.

116.—CADMIUM—(*Cd*).

In color and lustre has a strong resemblance to Tin, but is somewhat harder and more tenacious. It is very ductile and malleable. It melts at about the same temperature as Tin, and is nearly as volatile as Mercury, condensing like it into globules which have a metallic lustre. Its vapor has no odor.

Cadmium is readily oxidised and dissolved by Nitric Acid, which is its proper solvent.

The Oxide of Cadmium is of a brown or yellowish brown color; its Hydrate is white. They are both easily soluble in the dilute mineral Acids. The Salts of Cadmium are colorless, provided the constituent Acid be so. Most of them are soluble in water. The soluble neutral ones redden Litmus paper, and are decomposed at a red heat. This metal occurs only in Zinc ores. It is found as Sulphide in Zinc Blende, and as Oxide or Carbonate in Calamine.

When compounds of Cadmium, mixed with Carbonate of Soda or other reducing agents, are exposed on Charcoal to the inner blowpipe flame, the Charcoal becomes covered with a yellow or reddish yellow incrustation of Oxide of Cadmium.

117.—GOLD—(*Au.*)—

Is commonly alloyed when found in the metallic state with other metals, as Silver, Tellurium, Copper, and Iron.

It is soft, like Silver, softer than Copper, and fusible without difficulty.

Its crystalline form is cubic, with pyramids on the faces.

Gold may be freed from foreign matters by smelting with some flux, as Borax (after clearing it as much as possible by mechanical processes, stamping, washing, and sometimes by roasting,) to separate the stony matters.

Or it is fused with Lead, and afterwards submitted to cupellation. Or amalgamated with Mercury, and after straining distilled.

The separation of Gold from Silver (parting) may be effected in the dry way by fusion with Sulphur, by which metallic Gold and Sulphuret of Silver are procured. Or in the wet way, by the process of quartation; that is, by treating an alloy of three parts of Silver and one of Gold, with Nitric Acid, which dissolves the Silver, but not the Gold.

From its combinations with Tellurium, it may be easily separated on Charcoal. If the globule so obtained is white, it contains more Silver than Gold, and must be digested in a Porcelain capsule with hot Nitric Acid, in which the globule turns black, and the Silver is gradually dissolved, provided not more than one-fourth of it is Gold. When the quantity of Gold is larger, Nitro-muriatic Acid must be used, which dissolves the Gold.

Gold and Platinum produce re-actions so decisive, the former with Chloride of Tin, and the latter with Chloride of Ammonium, that their presence may invariably be detected in the presence of all the other metals. An original solution may therefore in all cases be examined for these substances.

Peroxide of Gold ($Au\ O_3$) is of a deep brown color; its Hydrate being somewhat lighter in color. They both dissolve readily in Hydrochloric Acid, but are insoluble in dilute Oxygen Acids.

Persulphide of Gold ($Au\ S_3$) is black.

Nos.	Tests for GOLD.	Precipitates.
1.	Potash, ...	None, if the Potash is in great excess.
2.	Ammonia and its Carbonate, ...	Yellow fulminating Gold by Ammonia. By the Carbonate there is also a disengagement of Carbonic Acid.
3.	Oxalic Acid and Sulphate of Protoxide of Iron, ...	Black metallic Gold in powder.
4.	Ferro-cyanide of Potassium, ...	Emerald green color.
5.	Protochloride of Tin, ...	Brown of variable shades.
6.	Hydrosulphuric Acid, ...	Black.
7.	Sulphide of Ammonium, ...	Black, soluble in excess of the test.
8.	Zinc,...	Brown metallic Gold.

118.—ARSENIC,—(*As.*)

Metallic Arsenic is solid, of a steel grey color, of a granular or scaly texture, and glistening when freshly prepared; very friable, insipid, slightly odorous when rubbed, volatile; it can be sublimed, and it crystallizes in octahedra; when heated it flies off in dark fumes, accompanied with an odor of garlic, and the vapor is converted into white Arsenious Acid by contact with the Oxygen of the air.

There are two varieties of Arsenious Acid, which are perfectly distinct in their physical characters and chemical properties. One, from its appearance, is termed the vitreous and the other the milky variety; when heated they volatilize in white inodorous fumes. Both kinds are more easily soluble in hot than in cold water. It unites with bases forming a class of Salts called Arsenites, which are all insoluble in water, with the exception of the Alkaline Arsenites. Sulpharsenious

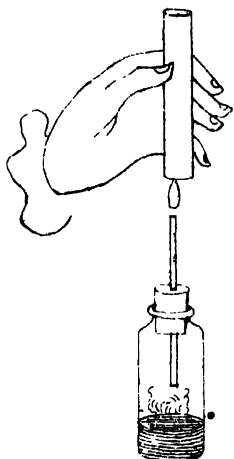
Acid ($As\ S_3$) is yellow and soluble, not only in the Alkalies and Alkaline Sulphides, but likewise in the Alkaline Carbonates.

Lime water is occasionally employed for detecting the presence of Arsenic, with the solutions of which it forms a white precipitate (Arseniate of Lime), which, being scarcely more soluble than Sulphate of Lime, sinks to the bottom in the form of minute crystals, and when laid on an ignited piece of Charcoal, diffuses the Alliaceous or Garlic odor peculiar to Arsenic. Arsenic is sometimes precipitated in solution by Nitrate or Acetate of Lead, as the Arseniate of Lead.

Antimony and Arsenic in their *nascent* state, combine with Hydrogen, forming inflammable gaseous compounds, which burn with a bluish white flame; water and Oxide of Antimony in the one case, and water and Arsenious Acid in the other being formed.

Hence is derived the best test of Arsenic as a poison, which is the following, called Marsh's Test. It must be performed with great care, and with fresh and clean materials and apparatus, each time, to ensure an accurate result.

A portion of the liquor supposed to contain Arsenic must be introduced into a small 2 oz. glass phial with wide mouth, together with a small piece of Zinc and a little dilute Sulphuric Acid (one to seven of water) to generate Hydrogen Gas.



If no Arsenious Acid be present, the evolved Gas is Hydrogen, but if the liquor hold Arsenic in solution, Arseniuretted Hydrogen will be formed.

That Gas must be allowed to escape through a small glass tube or piece of tobacco pipe, passed through the cork of the bottle. It will at first burn with its proper yellow color, but if it be Arseniuretted Hydrogen, it will burn with a bluish white flame, and have an alliaceous odor or smell of garlic or onions, and it will deposit in a glass tube about $\frac{1}{4}$ or $\frac{1}{2}$ an inch wide, and 9 or 10 inches long, held perpendicularly over it, black metallic Arsenicum and white Arsenious Acid for the space of several inches.

A solution of the sublimate may now be obtained and tested, according to the method previously given.

If Hydrochloric, instead of Sulphuric Acid, be used, Zinc stains are apt to be produced by the Chloride of Zinc formed, which is volatile. Hence it is advised in this case to place pieces of Asbestos or powdered

China in the tube, which will prevent the Zinc from being mechanically carried up.

Sometimes a Porcelain plate is held near the flame, upon which the stains of Arsenic, of a brownish fawn color, more or less deep, brilliant and glistening will be produced. If the current of Hydrogen be very strong, however, other stains, arising from the Lead or Tin of the glaze of the Earthenware, if of common manufacture, are likely to be produced.

Stains from other metals are also liable to be produced, as from Iron, Sulphur, Charcoal and Phosphorus. These (and the abovementioned ones) must be tested by the tests respectively applicable to them.

As Antimoniuretted Hydrogen is so similar to Arseniuretted Hydrogen, and as Tartar Emetic (a compound of Antimony and Tartrate of Potash) is frequently given as an antidote in cases of poisoning, this becomes the most important substance to distinguish.

If the tube, through which the Gas is passing, be heated, a metallic ring is formed, if it be Arseniuretted Hydrogen, a little in front of the heated point, whilst if it be Antimoniated Hydrogen the ring is formed in the part of the tube to which the heat is applied.

Antimonial stains are instantly dissolved by Nitric Acid, but the solution, when evaporated, leaves a *yellowish* white residue of Antimoniate of Protoxide of Antimony, which does *not* produce a brick red precipitate in a concentrated solution of Nitrate of Silver. The residue from the treatment of Nitric Acid, when placed in contact with Hydrochloric Acid, dissolves, and the solution, when treated with Hydrosulphuric Acid, produces an *Orange* yellow precipitate which is *not* soluble in Ammonia.

Nos.	Tests.	Arsenical Stains.	Antimonial Stains.
1	Appearance and color,	Bright glistening, brown color, where margin becomes thin,	Dark sooty black stain, not bright, brown at the margin.
2	Heated by the flame of pure Hydrogen,...	Disappear rapidly, ...	Disappear with difficulty, and leave a residue of white Oxide of Antimony.
3	Chloride of Soda, (Hypochlorite), ...	Dissolve instantly, ...	Do not dissolve.
4	Alcoholic Tincture of Iodine, ...	Dissolve after some time, ...	Dissolve with more difficulty, and leave a red stain.
5	Watery solution of Iodine, ...	Solution very evident,	Solution almost entirely absent.
6	Iodide of Potassium and Iodine, ...	Do not dissolve, ...	Dissolve immediately.

The above characters suffice in the main to distinguish these two kinds of stain, and the additional proofs, by Nitric and Hydrosulphuric Acid, furnish very precise distinguishing characters.

ARSENIC ACID—($As\ O_5$).—This Oxide is white. It is deliquescent and strongly acid, forming with bases a class of Salts called Arseniates, which are all insoluble in water, with the exception of the Alkaline Arseniates. It fuses at a low red heat without undergoing decomposition, but at a higher temperature is resolved into Oxygen and Arsenious Acid, which volatilize. Sulphurous Acid, aided by a gentle heat, reduces it likewise to this lower state of oxidation. The metal Arsenic is found in nature principally as Sulphide.

Combined with other metals, Arsenic destroys their good qualities more than it increases them. It makes Gold brittle; Platinum fusible and liable to fractures; Iron "red rotten," or incapable of being worked. With Copper it forms an alloy which has been used for optical mirrors; mixed with Lead to the extent of 2 per cent., it facilitates its formation into the small globules of shot, and makes the metal harder.

Sulphuret of Arsenic (Realgar) behaves under the blowpipe like Arsenic. Most of the Arsenides on Charcoal in the inner flame yield a white deposit at a distance from the assay; or when the proportion of Arsenic is large, grey vapors, having a smell of garlic.

119.—ANTIMONY,—($Sb.$)—

Called in German, Speiss Glance, from the brilliant needle and spear (Speiss) shaped crystals, which are the peculiar form of the ordinary Antimonial Ore. It may be distinguished by its grey powder immediately assuming a yellow ochre color when heated with Caustic Potash.

It is generally found as the Sulphuret ($Sb_2\ S_3$) of an Orange red color, which fuses and is dissipated before the blowpipe with the smell of Sulphurous Acid and the formation of a white smoke. Digested in Hydrochloric Acid, it evolves Hydrosulphuric Acid, and forms a solution of Sesquichloride of Antimony, which produces a whitish precipitate (powder of Algaroth or Oxychloride of Antimony) with water, and an orange red one with Hydrosulphuric Acid (see Arsenic.)

The Oxide ($Sb\ O_3$) occurs either in the form of white brilliant crystalline needles or as a greyish white powder, according to its mode of preparation. It fuses at a gentle red heat, and at a higher temperature volatilizes unaltered. The solubility of this Oxide in Tartaric Acid distinguishes it from Tin, Arsenic, Gold, and Platinum. When fused along with Nitrates it is converted into a higher Oxide (Antimonic Acid, $Sb\ O_5$).

Some of the Salts of Antimony are decomposed by ignition—some are volatilized unaltered. The soluble neutral Salts redden Litmus paper. When treated with a large amount of water they are decomposed into soluble Acid and insoluble Basic Salts. Antimony in solution is, in consequence, often precipitated by affusion with much water. In this respect they resemble the Salts of Bismuth, with this exception, that the insoluble Basic Salts of Antimony dissolve in Tartaric Acid, whilst the corresponding Salts of Bismuth are insoluble.

Most minerals in which Antimony is combined with Sulphur and other metals, afford the same re-action as Antimony itself under the blowpipe, *i. e.* melting and subliming with a white crystalline deposit. Oxide of Antimony also affords a faint greenish blue color to the flame.

120.—NICKEL—(*Ni.*)

The color of its Oxide is grey; its Hydrate is green. Its Salts likewise exhibit this latter color, except when anhydrous; in this state they are mostly yellow. The soluble Salts redden Litmus paper, and are decomposed at a red heat.

The principal minerals of this metal are the Arsenical Nickel ($Ni\ As$) and Nickel Glance ($Ni\ S_2 + Ni\ As_2$.)

Solutions of Salts of Oxide of Nickel have a bright green color, and yield with Potash a bright green precipitate of Hydrate of Oxide of Nickel, which is unchangeable in the air, but is soluble in Carbonate of Ammonia.

Oxide of Nickel and its compounds being first roasted, give to beads of Borax in the outer blowpipe flame, a reddish or violet brown bead, which when cold is yellowish or dark red; an addition of Nitre changes the color into blue, by which means Oxide of Nickel may be distinguished from Oxide of Iron. In the inner flame the color disappears and the Lead becomes grey with finely divided metallic Nickel. The appearances with Salt of Phosphorus are the same, except that the color vanishes almost entirely when the bead becomes cold. The addition of Nitre, changes the color to a bluish purple.

Nickel is very difficult to be purified; it is magnetical and even acquires polarity by the touch. Together with Copper and Zinc it forms "German Silver," which is 2 Copper to 1 of Nickel and 1 of Zinc.

121.—COBALT—(*Co.*)

The color of this Oxide is grey; its Hydrate being pale red. The Salts of Cobalt when anhydrous are blue, in the hydrated state they are red. Their solutions exhibit this color even when very dilute. The soluble

salts redden Litmus paper and are decomposed by heat. The principal mineral of this metal is the bright white Cobalt ($Co\ As_2 + Co\ S$).

The compounds of Cobalt impart to beads of Borax in both flames of the blowpipe a beautiful blue color, which is a very characteristic test of this Oxide.

A solution of Cobalt may be made by acting on the native Arseniuret with Sulphuric, mixed with a fourth part of Nitric Acid. Through the solution if Sulphuretted Hydrogen be passed, the Arsenious Acid will be separated as the black Sulphuret of Arsenic. The filtered liquid is then boiled with Nitric Acid to peroxidize the Iron and an excess of Carbonate of Potash added. The precipitate (Peroxide of Iron and Carbonate of Cobalt) after being well washed with water, is digested in a solution of Oxalic Acid, which dissolves the Iron and leaves the Cobalt as an insoluble Oxalate.

It is a constant ingredient (like Nickel) of Meteoric Stones.

Alkaline Sulphides precipitate it as a black Sulphuret of Cobalt. Sulphuretted Hydrogen produces no change, unless the solution is quite neutral, or the Oxide is combined with a weak Acid.

Muriate of Cobalt forms a sympathetic ink. Smalt is prepared from an impure Oxide, called " Zaffre."

CHROMIUM—(*Cr.*)

The color of this Oxide is green: its Hydrate is bluish grey. The solutions of its Salts possess a beautiful green color by reflected and reddish violet color by transmitted light. Sulphide of Chromium is decomposed in contact with water into Oxide of Chromium and Hydrosulphuric Acid.

When Oxide of Chromium or any of its compounds are fused with Nitrate of Potash, it becomes converted into a higher Oxide, *viz.*, Chromic Acid, which, combining with the Potash, forms yellow Chromate of Potash. This test distinguishes it at once from all other substances.

Borax dissolves Oxide of Chromium and its Salts both in the inner and outer blowpipe flame: the bead on cooling assumes an emerald green color; Microcosmic Salt has the same effect.

In the fixed Alkalies, a small quantity of Oxide of Chromium in the presence of a large quantity of peroxide of Iron, is totally insoluble; but a small quantity of the latter dissolves readily, when a large quantity of the former is present. Under these circumstances the two Oxides are best separated from each other by fusing the mixed substances with Nitre and Carbonate of Soda, and treating the fused mass with water; the Chromate of Potash dissolves in the liquid, the Peroxide of Iron remains behind.

122.—BISMUTH—(*Bi*)—

Is a reddish white metal, without taste or smell. It is moderately hard, brittle, pulverizable, and fusible at a red heat. When strongly heated in the air it takes fire, and burns with a faint blue flame, emitting a yellow smoke, which is the Oxide. It is soluble in Nitric Acid, tardily so with Muriatic and Sulphuric Acids. Water throws down a white precipitate, decomposing it into soluble Acid Salts and insoluble Basic ones, but an excess of Acid prevents this decomposition.

This property is exhibited in the most decided manner by the Chloride. To employ it as a confirmatory test, dissolve the precipitate in a small quantity of Hydrochloric Acid, evaporate nearly to dryness, and pour this solution into a large quantity of water. If Bismuth be present, a milky turbidness will be produced.

Any Arsenic in the Bismuth is detected by the Nitric Acid, which converts it into an insoluble Arseniate.

The Salts of Antimony, which are also decomposed by water, exhibit many re-actions similar to those of Bismuth; but they are distinguished by Hydrosulphuric Acid, and the soluble Sulphurets, which cause an orange yellow (not black) precipitate with the Salts of Antimony.

The Oxide is of a yellow color; its Hydrate is white. They are both readily soluble in the dilute mineral Acids. Most of the Salts of Bismuth are decomposed at a red heat. They are colorless, provided the constituent Acid be so.* The soluble neutral Salts redden Litmus paper.

Eight parts Bismuth, five of Lead and three Tin, constitute the fusible metal, (sometimes called Newton's from its discoverer,) which melts at the heat of boiling water, and may be fused over a candle in a piece of stiff paper without burning it.

One of Bismuth, five Lead and three Tin, form Plumbers' solder.

Nos.	Tests for BISMUTH.	Precipitates.
1	Potash and Ammonia, ...	White, insoluble in an excess of the test.
2	Soluble Carbonates, ...	Ditto.
3	Ferro-cyanide of Potassium,... ...	White, insoluble in Hydrochloric Acid.
4	Ferri-cyanide Ditto, ...	Yellow, soluble in Ditto.
5	Tannin, ...	Orange yellow.
6	Hydrosulphuric Acid and Soluble Sulphurets, ...	Brown or Black.
7	Chromate of Potash, ...	Yellow.
8	Plate of Zinc, ...	Metallic Bismuth.

* When compounds of Bismuth mixed with Carbonate of Soda are exposed on Charcoal to the inner blowpipe flame, *brittle* metallic globules are obtained, attended with a yellow incrustation of Oxide of Bismuth.

Bismuth melts very easily under the blowpipe, and sublimes with a yellow incrustation. In the open tube it gives off no vapor, but is surrounded by melted Oxide, which appears dark brown when warm, and bright yellow when cold.

An Assay containing Copper (previously roasted if its appearance is metallic) being fused with Borax or Salt of Phosphorus in the inner flame, the bead is opaque and of a reddish brown color, which may be increased by the addition of a little Tin. In the outer flame the bead while hot is green, and blue when cold.

123.—COPPER (*Cu.*)

This metal is sometimes found in the Native state, but it chiefly occurs in combination with Sulphide of Iron constituting the Copper Pyrites ($Cu_2\ S + Fe_2\ S_3$), and in blue Copper Ore or Malachite ($2\ CuO, CO_2 + HO.$) The Ores of Copper are found in Bituminous Marly Slate of the New Red Sandstone formation in Germany. In Sweden and Africa in veins in primary Mica Slate. In Russia in primary Slate and secondary Sands and Clays. In England chiefly in the primary Rocks, as Granite, Porphyry and Trap, and also in the Mountain Limestone and Grit at the base of the Carboniferous formation. It is associated in its veins with Quartz and Fluor Spar, and the veins are usually from 3 to 6 feet broad.

Nos.	Tests.	Salts of Suboxide.	Salts of Protoxide.
1	Potash and Soda, ...	Brownish yellow precipitate insoluble in an excess of re-agent,...	Bluish white precipitate, insoluble in excess of the re-agent, and which becomes black when boiled.
2	Ammonia, ...	Precipitate soluble in excess of the re-agent, forming at first a colorless solution, which becomes blue on contact with the air, ...	Blue or green precipitate, which is dissolved by an excess of Ammonia, forming a beautiful deep blue solution (not very delicate.)
3	Ferro-cyanide of Potassium, ...	White precipitate which becomes brown on exposure to air,...	Maroon brown precipitate (very delicate.)
4	Ferri-cyanide Ditto, ...	....	Greenish yellow precipitate.
5	Sulphide of Ammonium,	Brown, ...	Black, insoluble in an excess of re-agent.
6	Hydrosulphuric Acid,...	Ditto, ...	Black.
7	Iodide of Potassium, ...	Ditto, ...	Bluish white.
8	Tannin,...	Ditto, ...	Grey.
9	Chromate of Potash, ...	Ditto, ...	Red brown.
10	Clean Zinc or Iron, ...	Metallic Copper,... ...	Metallic Copper.

Acid, Alkaline, Saline and Fatty bodies, when placed in contact with it in the air, especially if melted and *allowed to cool* in it, promote its union with Oxygen; and by dissolving a portion of the newly-formed Oxide, acquire poisonous properties.

The substance, called Verdigris or Verdet, is in reality only Hydrated Bioxide, or Hydrocarbonate of Copper, and though called Acetate, seldom contains that, or Oxalic or other Acids, unless Acids have been placed in contact with metallic Copper. Verdigris is a *basic* Acetate of Copper, that is, having more equivalents of the Base than of the Acid.

The Oxide is black, its Hydrate is of a light blue color. They are both readily soluble in the dilute Mineral Acids. Most of the Salts of this metal are soluble in water. The soluble ones redden Litmus paper and are decomposed at a red heat.

In their Anhydrous state the Salts are white, in their Hydrated state, they are of a blue or greenish blue color, which their solutions exhibit, even when much diluted.

When bright Iron is made use of as a test on which to precipitate it, it is important that the solution should be only slightly acid. It is best to acidulate slightly with Hydrochloric Acid.

When we wish to recognize the presence of Copper in colored liquids, we may decolorize them by well-washed animal Charcoal, and then prove the existence of the Copper by the tests above given. If the solution is transparent, we may pass a stream of Sulphuretted Hydrogen, and boil the Sulphuret of Copper thus obtained in pure concentrated Nitric Acid, which will form Sulphate of Copper, which is easily recognized; but if the liquid is viscid, we must first boil it and then operate upon the filtered liquid as we have just mentioned, and treat the coagulum with concentrated Nitric Acid.

Copper Pyrites may be distinguished from Iron Pyrites, by boiling it with Nitric Acid which decomposes it, adding an excess of solution of Ammonia and pouring off the solution from the precipitate.

It may also be distinguished from similar Ores containing no Copper, by melting it before the blowpipe, moistening the tested particle with Hydrochloric Acid, and again bringing it before the blowpipe, when it imparts for a short time a beautiful blue color to the flame. This is applicable to the detection of all the other compounds of Copper.

The compounds of Copper with Carbonate of Soda on Charcoal in the inner blowpipe flame, produce metallic Copper without any incrustation.

124.—LEAD. (*Pb.*)

Lead Ores are found in Transition Strata, and as far as the carboniferous formation but not above that. In Scotland, it is in veins 4 to 10 feet thick in Greywacké, and in its veins it is usually associated with Quartz, Fluor, or Calc Spar.

The Oxide of Lead is of a yellow or reddish yellow color. It stains the fingers bluish grey when rubbed. In commerce it frequently goes under the name of Massicot, and when partially fused is called Litharge. The hydrated Oxide is of a white color, and it speedily absorbs Carbonic Acid from the air. The best solvent, both for the Oxide and its Hydrate, is Nitric, or Acetic Acid. Hydrochloric Acid acts feebly on it. The Salts of Lead are frequently insoluble and are colorless if the constituent Acids be so. The soluble neutral Salts redden Litmus paper, and are decomposed at a red heat. The principal minerals of this metal are the Sulphide (Galena or Lead Glance $Pb\,S$) and the Carbonate ($PbO,\ CO_2$).

The presence of organic matters does not prevent the Salts of Lead from being precipitated by Sulphuric Acid, and soluble Sulphates, and Hydrosulphuric Acid. The sulphate is white; the sulphide black.

Iron, Zinc and Tin precipitate Lead from its solutions forming the "Arbor Saturni" or "Lead tree," which is produced more easily when the liquid is acidulated with Nitric Acid.

Oils dissolve the Oxide of Lead, and become thick and consistent; in which state they are used as the basis of paints and plasters.

The powder precipitated from the solution of the Nitrate of Lead, being dried, forms the yellow Protoxide, commonly called Massicot; when somewhat vitrified it constitutes Litharge, and combined with Carbonic Acid, White Lead.

Hydrochloric Acid produces a white Chloride of Lead, which is unchangeable in Ammonia, but is soluble in a large quantity of hot water.

Lead, from not being expensive, like Porcelain, or brittle, like Stoneware, or subject to the influence of Sulphuric Acid, like Iron, Tin and Copper (at least to so great an extent), is much used in chemical manufactories.

Its alloys in chemical combinations are also much used. In type-founding, in glass-making, glazing earthen-ware; in making paints (the Oxide or Litharge, the white Carbonate, &c.), in medicine (the Acetate or Goulard extract, &c.)

Lead glazes, dissolved off earthen vessels by vinegar, and lead shot

left in bottles cleaned by them and remaining long in contact with wine, have often acted as poisons.

Nos.	Tests for LEAD.	Precipitates.
1	Potash or Soda, ...	White, soluble in an excess of re-agent.
2	Ammonia, ...	White, insoluble in excess of re-agent.
3	Soluble Carbonates, ...	White, insoluble ditto ditto.
4	Ferro-cyanide of Potassium,... ...	White.
5	Ferri-cyanide of Potassium, ...	No precipitate.
6	Tannin, ...	Yellow Salt.
7	Hydrosulphuric Acid and Soluble Sulphurets, ...	Black, insoluble in an excess of the re-agent.
8	Sulphuric Acid and Soluble Sulphates, ...	White.
9	Soluble Iodides, ...	Yellow (soluble in boiling water.)
10	Neutral Chromate of Potash, ...	Bright yellow.

Lead compounds mixed with Carbonate of Soda on Charcoal, form in the blowpipe flame, ductile metallic globules, accompanied with an incrustation, which is yellow whilst hot, but becomes paler on cooling.

125.—MERCURY (*Hg*).

Mercury is found united to Silver in the Ore called Native Amalgam of Silver. It is obtained chiefly from the Bisulphuret or Native Cinnabar. It is very volatile. Mr. Faraday has shown that at common temperatures, and even when the air is present, Mercury is always surrounded by a mercurial atmosphere. When invisible to the naked eye and in a finely divided state, it may be readily detected by the white stain (called by workmen "quickening") communicated to Gold and Silver. At 40° below Zero it solidifies.

Cinnabar is found in the primary rocks, and also in the older secondary or Bituminous and indurated Shales of the coal formation. The prolific mines of Almada in Spain are in Sandstone and Shale.

Protoxide or Suboxide of Mercury is black. It is decomposed by heat, the Mercury volatilizing in the metallic state. It forms no Hydrate. The soluble neutral Salts, also those of the Peroxide, redden Litmus paper; some of them, the Sulphate and Nitrate, are decomposed by much water alone, into soluble acid and insoluble basic Salts. The color of the neutral Salts is white, the color of the basic ones is yellow. They are reduced (also the Persalts), like the Silver Salts, by many metals, such as Zinc, Iron, Copper, &c., and by other reducing agents.

The Peroxide is obtained in the form of a crystalline mass, nearly black whilst hot, (at a red heat it is decomposed and entirely volatilized,)

but of a light red when cold. Its Hydrate is yellow. Both Oxide and Hydrate are soluble in Hydrochloric and Nitric Acid.

Nos.	Tests.	Protoxide Salts.	Binoxide Salts.
1	Potash or Soda, ...	Black precipitate, ...	Orange yellow precipitate.
2	Ammonia, ...	Ditto, ...	White precipitate.
3	Hydrosulphuric Acid,...	Ditto,...	Yellow or greyish white precipitate in the first instance, which varies in color and becomes black with an excess of the test.
4	Soluble Sulphurets, ..	Ditto, ...	Ditto.
5	Iodide of Potassium,..	Greenish, yellow precipitate, ...	Bright red (sometimes yellow at first) precipitate, which is soluble in an excess of the test (forming a perfectly colorless solution.)
6	Chromate of Potash, ...	Bright red precipitate,..	Reddish yellow precipitate.
7	Protochloride of Tin,...	Black precipitate, ...	Precipitate white at first, but black with an excess of test.
8	Hydrochloric Acid & soluble Chlorides, ...	White precipitate, ...	No effect.
9	Gold or Copper Wire (with a thread of Zinc folded spirally round it) Smithson's Galvanic pile, ...	Metallic Mercury, ...	Metallic Mercury.
			(*N. B.*—The liquid may be acidulated with a few drops of Hydrochloric Acid.)

Copper plates scraped perfectly clean are extremely sensible in the detection of Mercury. Morfila is persuaded that by this process he can recognize the presence of an 80,000 part of Corrosive Sublimate (the Perchloride); Mercury when deposited upon Copper, leaves a grey stain, which becomes bright when rubbed with a cork, but if the mercurial compound is mixed with a soluble Chloride, the stain will be white. The grey color is owing to a mixture of metallic Mercury with a little Oxide or Chloride, and when this is removed by Ammonia or by Hydrochloric Acid, the Mercury then assumes its white color. If the solution be concentrated by boiling in a close vessel the better. The plates also must be perfectly clean. When the Mercury has been deposited upon a plate of Copper, and the stains have been washed with Ammonia (a weak solution), and then in distilled water, we may test them by

pressing them between two leaves of tissue paper; then cut them into small pieces and put them into test tubes drawn out so as to taper at their extremity; and on heating them the Mercury volatilizes, and is condensed upon the most tapering part of the tube (see Perchloride of Mercury).

Mercury and all compounds of Mercury yield a sublimate of metallic Mercury when they are heated in the matrass, either alone or with the addition of Tin or Soda.

126.—SILVER (*Ag.*)—

Is found sometimes nearly pure, or alloyed with Gold, Antimony, Arsenic, Copper, &c., or combined with Sulphur, Selenium, Iodine, Chlorine, or united to Oxygen and Carbonic Acid. Of these, Native Silver and the Sulphuret are by far the most abundant.

Most Silver is either found pure, or is extracted from the Lead Ore. In the South American Mines it is found pure in veins of great width at great elevations of 8 and 9,000 feet, and chiefly in Transition Rocks, Clay Slate, Greywacké and Limestone. Sometimes, as at the Chota Mines, it is even superficial, like Australian Gold, and again in Mexico it is found in strata, corresponding with the Magnesian and Jura Limestone.

The metal may be extracted by amalgamation or cupellation.

By the first the Ore is mixed with common Salt and roasted, by which the Sulphuret of Silver is converted into the Chloride of this metal. Water and Iron are then added to remove the Chlorine, and the disengaged Silver is finally dissolved in Mercury (amalgamation) and the solution submitted to distillation, by which the Mercury is volatilized and the Silver left behind.

Cupellation is the purifying of perfect metals in cupels or cupsmade of bone ashes or Phosphate of Lime, which suffer the baser metals to pass through when exposed to heat, and retain the pure metal. Lead is added to the compound and this (the Lead) at a due heat becoming vitrified, promotes the vitrification and calcination of such imperfect metals as may be in the mixture, so that these last are carried off in the fusible glass that is formed, and the perfect metals are left nearly pure.

Silver is obtained from Argentiferous Galena (Sulphuret of Lead) as follows: the Ore is first roasted to expel the Sulphur, and afterwards smelted with Charcoal. The Argentiferous Lead is then submitted to cupellation, by which the Lead, becoming Oxidized, is partly volatilized and partly sinks into the cupel, leaving the Silver.

Pure Silver may be obtained by immersing a Copper rod in a solution of the Nitrate. The precipitate is to be digested in Caustic Ammonia to remove all traces of Copper, and afterwards washed with water.

The Mint process for assaying alloyed or impure Silver is as follows: 24 grains of the Alloy are dissolved in 1½ drams of Nitric Acid (at S. G. 1·2), a small quantity of water added, and the bottle containing the mixture placed on the Sand-bath, by the gentle heat of which it is dissolved, if only Silver, Copper, &c., are present. Sometimes more Acid is required if there are other Alloys, and if the Binoxide of Tin or Gold or Platinum be there, they would not be dissolved at all. More water is added to the bottle after the orange colored Nitrous fumes are dissipated or nearly so, and then 1½ drams Hydrochloric Acid at S. G. 1·16.

The Chloride of Silver is thus precipitated, its precipitation being much assisted by shaking up the bottle which collects it at once, leaving the supernatant liquid (containing Copper, &c.) nearly clear. This liquid is decanted after standing some time by syphon, washed and again allowed to settle.

The precipitate is then collected thus—The stopper of the bottle being removed, the finger is substituted for it, and the bottle reversed into a pan of water over a Porcelain cup, into which, on the removal of the finger, the whole precipitate falls. The cup is then removed, the superfluous liquid decanted, the precipitate dried in hot water or sand-bath, and all moisture thoroughly expelled by being subjected to a heat little short of its fusing point, or about 500. This great heat is necessary as all Chlorides (like common Salt) absorb moisture rapidly. The precipitate is therefore immediately weighed after drying. 100 grains of Chloride of Silver contain 75.3 Silver and 24.7 Chlorine.

If Lead or Mercury be present, they would also be precipitated by the Hydrochloric Acid. In this case there would be a turbidness in the solution, and the Chloride of Silver would not separate so readily. The method for separation of the Lead and Silver may be seen in the Analytical Tables at the end of Part II.

The color of the Oxide of Silver is brown. It is very soluble in Nitric Acid; it combines with Ammonia, giving rise to a dangerous compound (fulminating Silver.) Many of the Salts of Silver are colorless and insoluble. The soluble ones do not affect vegetable colors, and are decomposed at a red heat. Many of them blacken on exposure to light, and they are all decomposed with the precipitation of metallic Silver by many metals, such as Zinc, Iron, Copper, and other reducing agents.

The principal minerals of this metal are the Sulphide (Silver glance $Ag\ S$), the Chloride ($Ag\ Cl$), Sulphide of Silver and Arsenic (3 $Ag\ S + As\ S_3$), and Sulphide of Silver and Antimony (3 $Ag\ S + Sb\ S_3$.)

Nos.	Tests.	Precipitates.
1	Potash or Soda, ...	Brown, insoluble in Potash, soluble in Ammonia.
2	Ammonia (very weak,)	Brown, soluble in excess of Ammonia.
3	Carbonate of Potash, ...	White, soluble in Ammonia.
4	Phosphate of Soda,...	Yellow.
5	Ferro-cyanide of Potassium,... ...	White.
6	Ferri-cyanide ditto, ...	Reddish brown.
7	Hydrosulphuric Acid and soluble Sulphurets, ...	Black.
8	Iodide of Potassium, ...	Yellowish white, slightly soluble in Ammonia.
9	Hydrochloric Acid and soluble Chlorides, ...	White clotty, insoluble in water or in cold or boiling Nitric Acid. Soluble in Ammonia.
10	Zinc,...	Precipitates metallic Silver.

Silver compounds with Carbonate of Soda on Charcoal in the inner blowpipe flame give brilliant metallic Globules without incrustation.

On Charcoal, Silver may be reduced from many of its combinations. Other combinations and Sulphides, of which Silver is not an essential constituent, may be examined in the following manner:

The Assay in powder mingled with Borax and metallic Lead is melted on Charcoal, first in the inner flame and then for some time in the outer flame. The bead of Lead containing Silver thus obtained, is to be melted on a cupel of bone-ashes in the Oxidating flame till most of the Lead is Oxidized. The Lead being placed on a fresh cupel, the remaining Lead becomes Oxidized and sinks into the cupel, leaving the globule of Silver; in some cases the globule of Silver contains Copper or Gold.

127.—PLATINUM—(*Pt.*)—

Exists in Nature only in a metallic state. Its Ore has been found to contain Palladium, Iridium, Osmium and Rhodium, besides Iron and Chrome.

The mixture of which the grains of Platinum usually consist is soluble in hot Nitro-Muriatic Acid, leaving undissolved grains of Osmiridium.

In reducing it, the crude Platinum is to be dissolved in Nitro-Muriatic Acid, precipitated as Chloride of Platinum and Ammonium by

Muriate of Ammonia (or Sal-Ammoniac) and exposed to a very violent heat. Then the Acid and Alkali are expelled, and the metal reduced in an agglutinated state, which is rendered more compact by pressure while red hot.

Pure or refined Platinum is by much the heaviest body in nature. Its Sp. Gr. being 21.5. It is very malleable, though considerably harder than either Gold or Silver, and it hardens much under the hammer. Pure Platinum requires a very strong heat to melt it, and when urged by a white heat, its parts will adhere together by hammering.

Platinum is not altered by exposure to air, neither is it acted upon by the most concentrated simple Acids, even when boiling or distilled from it. Its only solvent (besides Nitro-Muriatic Acid) is Chlorine, which acts on it with more difficulty than on Gold.

Peroxide of Platinum ($Pt\ O_2$) is of a deep brown color, its Hydrate is reddish brown. Both the Oxide and its Hydrate dissolve readily in Hydrochloric Acid, but with difficulty in the Oxygen Acids, Persulphide of Platinum ($Pt\ S_2$) is of a blackish brown color.

Its presence can always be ascertained even amongst organic matters by the Chloride of Potassium or Ammonium, which produces with it yellow Crystalline precipitates, the presence of free Hydrochloric Acid promoting these.

Platinum and the metals which occur with it, cannot be separated from one another by the blowpipe.

Table of the Principal Elementary Substances, with their Chemical Equivalents.

Symbols.	Elements.	Equivalent.	Compounds.
	GASEOUS BODIES.		
O.	Oxygen, ...	8.0	HO Water.
H.	Hydrogen, ...	1.0	HS Sulphuretted Hydrogen; HC_2N or HCy Hydrocyanic or Prussic Acid.
N.	Nitrogen, ...	14.0	NO_2 Nitric Oxide; NO_4 Nitrous Acid; NO_5 Nitric Acid; NH_3 Ammonia. C_2N Cyanogen; NO Nitrous Oxide; (laughing Gas.) $Am. O. NO_5$ Nitrate of Ammonia.
Cl	Chlorine, ...	35.5	HCl Hydrochloric Acid; ClO_5 Chloric Acid; NH_4Cl. Chloride of Ammonium.
F	Fluorine, ...	20	HF Hydrofluoric Acid.
Br	Bromine, ...	80	HBr Hydrobromic Acid; BrO_5 Bromic Acid.
	NON-METALLIC SOLIDS.		
B	Boron, ...	10.9	BO_3 Boracic Acid.
C	Carbon, ...	6.0	CO Carbonic Oxide; CO_2 Carbonic Acid; $C_2 HCl_3$ Chloroform; C_8H_8 Oil Gas. C_2H_4 Carburetted Hydrogen Gas; C_4H_4 Olefiant Gas; $C_{12}H_6$ Benzol. $C_4H_6 O_2$ Alcohol; $NH_4O. CO_2$ Carbonate of Ammonia, (Sal Volatile); $C_8H_4O_{10}$ or $\overline{T}$ Tartaric Acid; C_2O_3 or $\overline{O}$ Oxalic Acid; $C_4H_3O_3$ or $\overline{A}$ Acetic Acid.
I	Iodine, ...	127.1	HI Hydriodic Acid; IO_5 Iodic Acid.
P	Phosphorus, ...	32	PO_5 Phosphoric Acid; PO_3 Phosphorous Acid; P_4H_3 Phosphuretted Hydrogen. $NaO. AmO. HOPO_5$ Phosphate of Soda and Ammonia.
Si	Silicon, ...	21.3	SiO_2 Silica.
S.	Sulphur, ...	16.0	SO_2 Sulphurous Acid; SO_3 Sulphuric Acid; $AmO. SO_3$ Sulphuret of Ammonia; NH_4S Sulphide of Ammonium.
	METALLIC BASES OF ALKALIES.		
K	Potassium (Kalium,) ...	39.0	KO Potash; $KO. CO_2$ Carbonate of Potash; $KO. NO_5$ Nitrate; $KO. ClO_5$ Chlorate; KCl Chloride; $KO. ClO_7$ Perchlorate; $KO. HO. T$ Bitartrate; $KCy_3 Fe$ or $KCfy$ Ferro-cyanide; KCy_6Fe_2 or $KCfy_3$ Ferricyanide; $KO. SO_3$ Sulphate; KBr Bromide; KI Iodide.
Na	Sodium (Natronium,) ...	23	NaO Soda; NaO 2 BO_3 Biborate of Soda; $NaO. NO_5$ Nitrate; $NaCl$ Chlorate; $NaO. CO_2$ Carbonate, $NaO. CO_2$, $HO. CO_2$ Bicarbonate; 2 $NaO. PO_5$ Phosphate; $NaO. SO_3$ Sulphate; $NaO. S_2 O_2$ Hyposulphite.
	METALLIC BASES OF EARTHS.		
Ba.	Barium, ...	68.5	BaO Baryta; BaS, Sulphide; $BaO. SO_3$ Sulphate; $Ba Cl$ Chloride; $BaO. CO_2$ Carbonate; $BaO. NO_5$ Nitrate.

Table of the Principal Elementary Substances, &c.—(Continued.)

Symbols.	Elements.	Equivalent.	Compounds.
Ca	Calcium, ...	20	CaO. Lime; $CaO.\ SO_3$ Sulphate of Lime; $CaO.\ CO_2$ Carbonate; $CaO.\ PO_5$ Phosphate; $CaO.\ NO_5$ Nitrate; CaF Fluor Spar; $CaO.\ Cl$ Chloride.
Mg	Magnesium, ...	12	MgO Magnesia; $MgO.\ CO_2$ Carbonate (Dolomite); $MgO.\ SO_3$ Sulphate of Magnesia (Epsom Salts); $Mg.\ Cl$ Chlorate; $2\ MgO.\ PO_5$ Phosphate; $MgO.\ NO_5$ Nitrate.
Sr	Strontium, ...	43.8	SrO. Strontium; $SrO.\ SO_3$ Sulphate; $SrO.\ NO_5$ Nitrate.
Al	Aluminum, ...	13.7	$Al_2\ O_3$ Alumina; $Al_2\ O_3\ SO_3$ Sulphate; $3\ Al_2\ O_3\ 2\ PO_5$ Phosphate.
	METALS, PROPER.		
Sb	Antimony (Stibium,) ...	129	$Sb_2\ S_3$ Sulphuret of Antimony.
As	Arsenic, ...	75	AsO_5 Arsenic Acid; AsO_3 Arsenious Acid; AsH_3 Arseniuretted Hydrogen;
Bi	Bismuth, ...	213	BiO_3 Oxide of Bismuth.
Cd	Cadmium, ...	56	CdO Oxide of Cadmium; $CdO.\ SO_3$ Sulphate; CdS Sulphide; $Cd\ Cl$ Chloride.
Cr	Chromium, ...	26.7	$Cr_2\ O_3$ Oxide of Chromium; CrO_3 Chromic Acid; $Cr\ Cl$ Chloride. $Cr_2\ Cl_3$ Sesquichloride; $KO.\ 2\ CrO_3$ Bichromate of Potash.
Co	Cobalt, ...	29.5	$CoO.\ SO_3$ Sulphate; $CoO.\ NO_5$ Protonitrate.
Cu	Copper, ...	31.7	$Cu_2\ S$ Copper Pyrites; $2\ CuO.\ CO_2.\ HO$ Malachite or Carbonate of Copper; $Cu\ Cl$ Chloride; CuO_2 Bi or Peroxide; $Cu_2\ O$ Red Oxide; $CuO,\ SO_3$ Sulphate or Blue Vitriol.
Au	Gold, ...	197	AuO_3 Peroxide; $Au\ Cl_3$ Perchloride; $AuO.\ SnO_2$ Purple of Cassius.
Fe	Iron (Ferrum,) ...	28	$Fe\ S_2$ Iron Pyrites; $Fe_7\ S_8$ Magnetic Pyrites; $Fe\ S$ Sulphide; $FeO.\ SO_3$ Proto Sulphate, (Green Vitriol); FeO Protoxide; $Fe_2\ O_3$ Peroxide; $Fe_4\ Cfy_3$ Ferro-cyanide of Iron Prussian Blue; $Fe_2\ Cl_3$ Perchloride; $Fe_3\ O_4$ Black Oxide.
Pb	Lead, ...	103.7	$PbO.\ NO_3$ Nitrate; $Pb.\ SO_3$ Sulphate; $Pb\ S$ Sulphide; $PbO.\ \bar{A}$ Acetate; $Pb\ Cl$ Chloride; $PbO.\ CO_2$ Carbonate.
Mn	Manganese, ...	27.6	$Mn\ S$ Sulphide; $Mn\ O_2$ Peroxide; $Mn\ Cl$ Chloride.
Hg	Mercury (Hydrargyrum,)	100	$Hg\ S$ Cinnabar (Sulphuret); $Hg\ Cl$ Protochloride; $Hg\ I$ Iodide. $Hg_2\ NO_5$ Protonitrate; $Hg\ O$ Red Oxide; $Hg_2\ Cl$ Protochloride (Calomel); $Hg\ Cl$ Perchloride (Corrosive Sublimate).
Ni	Nickel, ...	29.6	$Ni\ S$ Sulphide; $Ni\ Cl$ Chloride; $Ni_2\ O_3$ Peroxide.
Pt	Platinum, ...	98.7	$Pt\ Cl_2$ Bi or Perchloride.
Ag	Silver (Argentum,) ...	108.1	$Ag\ S$ Vitreous Silver (Sulphide); $Ag\ Cl$ Chloride; $Ag.\ NO_5$ Nitrate; AgS_2O_2 Hyposulphite.
Sn	Tin (Stannum,) ...	58	$Sn\ O_2$ Tin Stone (Peroxide); $Sn\ O$ Oxide; $Sn\ Cl$ Protochloride.
Zn	Zinc, ...	32.6	$Zn\ S$ Zinc Blende (Sulphide); $ZnO.\ CO_2$ Calamine (Carbonate); ZnO Oxide; $Zn\ Cl$ Chloride.

SECTION IV.

EXAMPLES OF ANALYSIS.

1.—The Analysis of Mineral Waters Quantitatively is by no means easy, and requires practised and skilful manipulation. A Qualitative Analysis however is much more easily made, and will, under most circumstances, be found to answer every purpose.

2.—The nature of the strata in the neighbourhood of a spring should always be noted. The period of the year when the Analysis was made, and whether after a rainy or dry season. The temperature as it issues forth should be observed, and the quantity yielded in a given time. Its taste, smell, degree of transparency, &c. are also best noted at the fountain head. Its specific gravity should be taken, and it is proper to examine on the spot the channel through which the water has flowed, to collect any deposit that may have been formed and to investigate its nature. The plants and vegetation in the neighbourhood should also be recorded, as far as the observer's botanical knowledge will permit.

3.—The effects of heat on the water may next be tried. Many waters lose their transparency when their temperature is raised and let fall a considerable deposit. The quality of this may, in some degree, be conjectured from its appearance. If its color be brownish-yellow, it consists either wholly or chiefly of Oxide of Iron. If white or nearly white it is composed principally of the earthy Carbonates. A mineral water containing Iron, deposits that metal also when exposed to the atmosphere, and a thin pellicle forms on its surface, whether stagnant in a natural reservoir or collected in a separate vessel. By this exposure Iron may be sometimes discovered in a water, though not easily detected at first, because it becomes further oxidized and more sensible to the action of tests. Sulphuretted Hydrogen Waters exhibit a sediment even when preserved in a well-closed vial; the Hydrogen quitting the Sulphur, which settles, in the form of a white powder.

4.—Water is never presented by nature in a state of complete purity. Even when collected as it descends in the form of rain, chemical tests detect in it a minute portion of foreign ingredients, and when it has been absorbed by the earth, has traversed its different strata, and is returned to us by springs, it is found to have acquired

various impregnations. In many instances, however, Mineral Water may contain a saline or other ingredient, but in such small quantity as to escape discovery by tests. It is advisable therefore to apply the tests of fixed substances to the water, after reducing its bulk one-half or more by evaporation, as well as in its natural state. The presence of Ammonia may be proved in Rain Water by simply adding a little Sulphuric or Hydrochloric Acid, and evaporating it nearly to dryness in a clean Porcelain vessel. The Ammonia remains in the residue in combination with the Acid, and may be detected by a little powdered Lime, which separates the Ammonia, and thus renders its peculiar pungent smell sensible.

5.—In River Waters the amount of sediment may be ascertained by mere subsidence, or better by filtration or evaporation, and the fine impalpable matter operated on, in a similar manner to that collected in the examination of a soil after affusion with water.

6.—An approach sufficiently accurate may be made to the quantity also of some substances, by merely ascertaining the quantity of the precipitate afforded by the use of a certain re-agent. Thus in using Nitrate of Silver to discover the quantity of that very commonly occurring ingredient Chloride of Sodium, or Common Salt, in water; If the total amount of the precipitate obtained and collected (which is Chloride of Silver) amount to 100 grains, this will indicate 42½ grains of common Salt in the water. Other instances of similar kind will be found given hereafter.

7.—Mineral waters may be divided into four classes as follows:—

1st.—Chalybeate or Ferruginous Waters.

2nd.—Sulphurous or Hepatic.

3rd.—Acidulous or Carbonated.

4th.—Saline, of which there are

1. Purging Saline, containing Sulphate of Soda, Glauber Salts, Sulphate of Magnesia, and Epsom Salts.
2. Brine, containing Chloride of Sodium, Iodine and Bromine.
3. Calcareous, containing Carbonate of Lime and Sulphate of Lime.
4. Alkaline, containing Carbonate of Soda.
5. Siliceous, containing Silica.

8.—A solution of white *Soap in Alcohol*, about 120 grains to a pint, may be used to test the *hardness* of waters caused by the presence of earthy or Metallic Salts, combining with which it produces immediately a milkiness, and a flaky precipitate will be deposited if the mixture be

left undisturbed for some hours. The milkiness is owing to such Salts as *Sulphate and Carbonate of Lime* (most usually encountered in well waters). The Alkali of the Soap (Soda) leaves the Oil with which it was combined, and unites with the Acid of the earthy bases of the Salts which are present in the water, and the Oil joins the liberated earths, and produces an insoluble precipitate, or earthy Soap.

The comparative hardness may be tested by shaking up the water violently with a measured portion of the Soap solution, so as to endeavour to produce a lather.

The harder the water, the more of the Soap solution will it require to produce the lather.

9.—*Alcohol* alone may be employed to test Mineral Waters. If these be well concentrated, and the Alcohol added be at least double that of the bulk of the fluid in which it is intended to act, it precipitates such saline bodies as are soluble in water, but insoluble, or nearly so, in Alcohol, as Sulphate of Magnesia, Sulphates of Soda, Potash, Alumina, and Lime and Nitrate of Potash. Also as it dissolves some of the substances found in Mineral Waters, as the Chlorides, and does not touch others, they may thus be separated into two classes.

10.—Most Mineral Waters contain earthy Salts with a fixed Acid, which remains in combination after boiling down the water to dryness, and which Acid is generally Hydrochloric or Sulphuric. The earths are generally Lime or Magnesia. In such a case, only four earthy Salts might be expected (not all together at once, for they would decompose each other) namely, Sulphate of Lime, Chloride of Lime, Sulphate of Magnesia and Chloride of Magnesia.

11.—Now of these Salts, the Sulphates are perfectly insoluble in Alcohol, but the Muriates are extremely soluble. If therefore the dry residue of the water be placed in a test tube or bottle, and a considerable portion of Alcohol poured upon it, and the solution allowed to stand for some hours with frequent agitation, it can contain only the Chlorides of Lime and Magnesia dissolved, (provided the Alcohol has been highly rectified; if not, it will also dissolve a little Chloride of of Sodium, should that be present.)

12.—The residue, which is not dissolved by the Alcohol, may contain the Sulphates of Lime and Magnesia, of which the latter Salt is easily soluble in water, but the former with great difficulty, unless assisted by an Acid.

13.—The presence of *Lead* in waters may be detected with great delicacy and certainty by *Sulphate of Soda* or *Sulphate of Potash,* and

these can be used in many cases with greater convenience than pure Sulphuric Acid. The Salt precipitates the white Sulphate of Lead, which is insoluble in water and in Ammonia, but soluble in dilute Nitric Acid assisted by heat, and which becomes blackened by water impregnated with Sulphuretted Hydrogen.

14.—*Iodine* is detected in water with very great accuracy by means of a simple solution of Starch. This is said to show the presence of the $\frac{1}{450000}$ part of Iodine in a liquid. The Iodine must, however, be in a free or uncombined state. When it is so, and a solution of Starch is added to the liquid containing it, it produces with it an Indigo blue color, and a precipitate (Ioduret of Starch) of the same hue is slowly deposited. When it is not so, but exists as Iodic or Hydriodic Acid, no change takes place, but if an Acid be added so as to disengage the Iodine, the Starch then instantly shows the presence of this substance by the Indigo blue color which it assumes. The precipitate, Ioduret of Starch, is soluble in dilute Sulphuric Acid forming a blue liquor, with concentrated Sulphuric Acid a brown compound, becoming blue on dilution.

15.—*Iron* is best detected by the Ferro-cyanide of Potassium. If it be in combination in a high state of oxidation (a Persalt), the precipitate is blue, and if a protosalt, white, but becoming subsequently blue on exposure. If Ferro-cyanide of Potassium be pure, it does not speedily assume a blue color on addition of an Acid, nor does it *immediately* precipitate Chloride of Barium. In testing with it, to render its effect more certain, a little Muriatic Acid should be first added (a drop or two), with a view to the saturation of uncombined Alkalis or earths which, if present, prevent the detection of minute quantities of Iron. If a Mineral Water taken *fresh* from the spring affords a blue precipitate with this Salt, but not after having been concentrated by boiling, it may be inferred that the Iron is present in the water in combination with Carbonic Acid, as the Iron will have been precipitated on the expulsion of the Carbonic Acid (which held it dissolved) by boiling. And if the test continue to strike a blue color with the boiled or concentrated water, the Acid, which held the Iron in solution, is a fixed or mineral Acid. If by boiling a yellowish powder be precipitated, and yet Gallic Acid continue to tinge the water black, the Iron, as often happens, is dissolved both by Carbonic Acid and by a fixed Acid.

16.—*Succinate of Ammonia*—an expensive Salt, is also sometimes used, but the Iron (if existing) must be first oxidized by boiling with a few drops of Nitric Acid to dryness. The powder is then re-dissolved with addition of water, the solution gradually mixed with dilute Ammonia,

until a slight precipitate is produced, which does not re-dissolve entirely, even on application of a gentle heat. A perfectly neutral solution of Succinate of Ammonia is now added as long as any precipitate is formed, the solution gently heated and allowed to stand for some time. The precipitate is filtered off, washed first with cold water, and afterwards with warm dilute Ammonia, which removes a part of the Succinic Acid, dried and ignited. In this way pure Sesquioxide or Peroxide of Iron is obtained.

17.—*Gallic Acid*, or *Tincture* of *Galls*, is used for the same purpose, as it produces with Iron a violet or black precipitate, whether the Iron be held in solution by Carbonic Acid, or by any other Acid. If it be as Carbonate, the precipitate or color is not produced after concentration by boiling, for the reason before given. And when the quantity of Iron is very small, as in most Chalybeate Waters, the effect is merely to produce a purple tinge.

18.—Another cause also affects the action of this test, *viz.*, the presence of Carbonate of Lime. When the Iron is in a low state of oxidation, it rather heightens the color, while, when it is at the maximum of oxidation, it diminishes it so much as to render it scarcely perceptible, if the Iron be in small quantity. Thus some of the Bath Waters have given indications of Iron, when fresh and hot, but after cooling and exposure, when the Iron has become more oxidized, they appear to give none, though no Iron is deposited during the cooling.

19.—*Sulphuretted Hydrogen*, of common occurrence in Mineral Waters, may be detected by holding over the water in a wine glass or test tube, a slip of paper moistened with any soluble Salt of Lead (Nitrate or Acetate), or with Nitrate of Silver, or Chloride of Bismuth. The paper will become blackened as the Gas escapes. The vapor of putrifying animal or vegetable matter dissolved in water, often gives a deceptive indication of Sulphuretted Hydrogen. Such water is also immediately rendered black by a drop of a solution of any of these Salts. *Litmus Paper* dipped into such water is also slightly reddened, but recovers its color by drying or exposure to a gentle heat. The same effect is produced on Litmus Paper by the presence of Carbonic Acid in the water, but the two Gases may be distinguished by the use of *Lime Water*, which produces a white precipitate of Carbonate of Lime immediately if the Gas be Carbonic Acid, but has no effect if it be Sulphuretted Hydrogen. Paper, stained with the juice of the violet flower, or the scrapings of purple radishes, produces the same effect as Litmus paper.

20.—*Litmus Paper* is reddened by water containing $\frac{1}{40935}$ part of Sulphuric Acid, but if the tincture of Litmus be used and dropped into large quantities of the water in transparent glass vessels, comparing two placed close together, one with, and the other without, the tincture, the test becomes much more delicate, even to 1 in 300,000 parts. The infusion of Litmus is prepared by steeping this substance, first bruised in a mortar and tied up in a piece of muslin, in distilled water, which extracts its blue color. In testing with Litmus Paper, the piece dipped into the water should be compared with a piece dipped into *distilled* water.

21.—*Potash* and *Soda* are distinguished by Tartaric Acid, which forms an insoluble crystalline precipitate with the former, but none with the latter; the Salt Tartrate of Soda being soluble in water. The Perchloride of Platinum produces the same effects with more delicacy, the precipitate with Potash being yellow.

22.—*Ammonia,* by the formation on evaporating of dense white clouds (Chloride of Ammonia condensing in contact with the moisture of the air) with the fumes of Hydrochloric Acid held over it on the extremity of a glass rod.

23.—*Turmeric Paper* will distinguish the *Alkalis,* free or combined with Carbonic Acid, from the carbonated *earths.* By the former it is reddened, while the latter do not affect it. In testing for Soda in Mineral Waters, it is advisable to evaporate or concentrate the water at a low heat to about $\frac{3}{4}$ or $\frac{1}{2}$ its bulk. Paper, to answer the purpose, may be made by making a slice of an entire turmeric root, wetting it with distilled water, and rubbing the paper with it, when a sufficient color will be obtained to test with.

24.—*Lime* is best detected by Oxalic Acid or Oxalate of Ammonia, which gives a precipitate soluble in Nitric and Hydrochloric Acids. Sulphuric Acid also detects it after some time, perhaps a few days, by forming Sulphate of Lime, but this Salt is soluble in 500 parts of water and particularly so if there be any excess of Acid. The solution must therefore be concentrated and allowed to cool, when the Sulphate of Lime separates in long transparent crystals. It may then be distinguished by its want of taste, difficult solubility when removed into pure water, and by affording a precipitate with Oxalic and Barytic Salts. When a liquor containing Selenite (Sulphate of Lime) is rapidly evaporated, this Salt separates as brittle shining laminæ. If the Oxalic Acid occasion a precipitate before, but not after boiling, the Lime is dissolved by an excess of Carbonic Acid.

Oxalate of Ammonia is preferable to the Acid, because it is not so liable to have its action impeded by a possible excess of Nitric or Muriatic Acid present with the Lime, and if this should be the case the solution should be first neutralized with Ammonia before adding the test. 117 grains Sulphate of Lime in the water will give 100 of Oxalate, at 160° Fahrenheit. The pure Lime may be obtained from the precipitate by calcination of the Oxalate into Carbonate, and then expelling Carbonic Acid by strong heat in a covered crucible.

25.—The presence of Hydrochloric Acid (or Chloride of *Sodium, common Salt,*) in water, which is of universal occurrence, is immediately detected by Nitrate of Silver, which forms with it the peculiar cloudiness of Chloride of Silver insoluble in Nitric Acid, soluble in Ammonia. One grain of Salt in 42,250 grains of water may be thus detected. In applying this test, certain precautions are, however, necessary, because it is also acted upon by alkaline and earthy Carbonates, and by Sulphuric Acid and its combinations. This may be guarded against by first removing the Sulphuric Acid by Chloride of Barium, and the action of the Carbonates may be prevented by super-saturating them previously with pure Nitric Acid.

The precipitate produced by the Carbonated Alkalis (Carbonate of Silver), is soluble in dilute Nitric Acid with effervescence.

26.—*Nitric* and *Muriatic* Acids in a dry state, or dissolved in very little water, are decomposed on adding Sulphuric Acid and applying heat, and vapors are evolved. In the former case these are yellow or orange colored; in the latter, if the wet stopper of the Ammonia bottle be held in them, there are white fumes. Both *Muriatic* and *Sulphuric Acid* may also be detected by the Acetate of Lead, as they form with it the Sulphide and Chloride of Lead, the former insoluble but the latter soluble in dilute Nitric and *Acetic* Acids; Nitric Acid is also thus detected in waters. To a concentrated solution is added ½ its bulk of concentrated Sulphuric Acid (perfectly free from Nitric Acid.) It is allowed to become nearly cool and a crystal of Sulphate of Iron dropped into it. After standing for some time at perfect rest, the presence of Nitric Acid will be indicated by a brown halo round the crystal.

The presence of Sulphuric Acid or the Sulphates is also tested by Chloride of Barium, or any Salt of Barytes, the insoluble Sulphate of Barytes being formed.

27.—*Magnesia* is detected by Phosphate of Soda. Magnesia is also precipitated partially by Ammonia, (the precipitate is soluble in Chloride of Ammonium) but completely, if Alumina be present. Phos-

phate of Magnesia and Ammonia is a Salt of difficult solubility. To a solution, therefore, containing Magnesia, add *neutral* Carbonate of Ammonia, prepared from some of the Salt which has been exposed, spread on a paper for a few hours to the air. No change takes place, as the Carbonic Acid of the Carbonate of Ammonia is sufficient to keep it in solution. But on adding a concentrated or saturated solution of Phosphate of Soda, the Salt before mentioned, Phosphate of Magnesia and Ammonia is precipitated. Let this be dried in a temperature not exceeding 100° Fahrenheit, 100 grains of it will indicate 19 Magnesia, or about 64 Chloride of Magnesia. Lime water also decomposes the Salts of Magnesia.

28.—*Carbonic Acid* is detected, as has before been observed, by *Lime Water*, which forms with it an insoluble precipitate of the neutral Carbonate of Lime. It should be observed that the Bi or Super-Carbonate of Lime is soluble in water and invisible therefore; but that if it has to part with any portion of its Carbonic Acid from heat and evaporation, either natural in the warm open air or artificial, then Lime (*i. e.* Carbonate of Lime) is deposited. Hence the origin, when this evaporation is rapid, of calcareous tuffs, &c., and when more slow, of Stalactites, calcareous petrifactions, &c.

29.—For the same reason when *Lime Water* is used as a test in small quantity, a precipitate is formed; but if a further portion of the water under proof is added, the precipitate is re-dissolved or taken up by the Carbonic Acid contained in the water; the soluble Bicarbonate is again formed. Another addition of Lime Water again precipitates it, or the same effect may be produced by boiling, which expels the Carbonic Acid. Hence also the reason of the crust or fur in kettles or vessels in which such water is frequently boiled.

30.—It must be remembered, in using this test, that Lime Water also decomposes the Salts of Magnesia, and is acted upon by Sulphates producing a precipitate of Sulphate of Lime which, however, unlike the Carbonate of Lime precipitate, is insoluble in Nitric Acid. Lime Water also detects the poisons, Arsenic and Corrosive Sublimate in solution, producing with the latter a brick-dust-colored precipitate, and with the former a difficultly soluble one in water, giving, when mixed with Oil and burnt on coals, the smell of garlic.

31.—Carbonic Acid and Sulphuretted Hydrogen are also detected, and better, by Baryta Water (prepared from crystals of Baryta) or Chloride of Barium. This forms precipitates with both Carbonate and Sulphate of Barytes, the former being soluble with effervescence, the

latter insoluble in Hydrochloric Acid. Phosporic Salts are also precipitated by the same agent, and the Phosphate of Barytes precipitate is soluble in Hydrochloric Acid without effervescence.

32.—Sulphuric Acid discovers, by a slight effervescence, the presence of Carbonic Acid, whether uncombined or united with Alkalies or earths.

33.—If two or three drops of Acetate of Lead be let fall into Water containing Carbonic Acid, a white precipitate of Carbonate of Lead is formed, which is soluble in Caustic Potash.

34.—*Phosphoric Acid* may be detected by Acetate of Lead, which produces with it a white precipitate of Phosphate of Lead soluble in Nitric Acid. A solution of Phosphate of Lime is completely decomposed by this Salt. The precipitate when dried at a low red heat contains 225 per cent. of Phosphoric Acid. A globule of pure Lead may be obtained from the precipitate before the blowpipe, the Phosphoric Acid burning off with a luminous vapor smelling of Phosphorus.

If Sulphuric Acid be present it will also be decomposed by the Acetate of Lead, Sulphate of Lead being formed; but this is separable from the Phosphate, as it is insoluble in dilute Nitric Acid.

35.—If *Oxygen* be present, in water, it may be proved with the aid of the green Protosulphate of Iron. If a small quantity be dissolved in the water contained in a well-stopped phial (filled full), and the solution continue clear, there is no Oxygen; but if otherwise, the liquid becomes, after some hours, slightly turbid, from the Oxide of Iron attracting the Oxygen of the Water, and a small portion of it in this more highly oxidated state, leaving the Acid, becomes precipitated of a brown or ochry color.

As common air, however, produces the same effect slightly, caution is requisite in drawing conclusions. 100 cubic inches of spring water have been found by one analysis (Mr. Henry) to yield 4.76 inches of Gas. Of these 3.38 inches were Carbonic Acid, and 1.38 Atmospheric Air.

36.—If, as is often the case, the Sulphates of Magnesia, Lime and Iron occur together, they may be thus separated.

If the excess of Acid (if any) be neutralized by Ammonia, Iron may then be precipitated by its appropriate tests, Succinate of Ammonia Ferro-cyanide of Potassium, &c.

Or the solution may be evaporated to dryness and then exposed to a dull red heat for at least an hour. By this means, the Sulphate of Iron becomes decomposed, its Oxide is left behind, and the Sulphate of

Lime will be rendered insoluble, while the Sulphate of Magnesia is not altered. If the mass be then digested in water, the last Salt becomes dissolved, and if Sulphate of Iron and Sulphate of Magnesia alone were present, the residue would of course be Oxide of Iron.

37.—If Sulphate of Lime and Sulphate of Magnesia be together in solution, the liquid should be concentrated highly, when after some hours repose, most of the Sulphate of Lime will separate alone (being comparatively insoluble) and may be removed. The solution may then be evaporated to dryness, ignited, digested with three or four times its weight of cold water, by which all the Sulphate of Magnesia will be dissolved, and what little Sulphate of Lime remained, will be left untouched. The solution may then be boiled with Carbonate of Potash to decompose the Carbonate of Magnesia, and the latter, when washed, dried and ignited, will be Magnesia.

38.—As a general rule the *Alkalies* (Potash, Soda and Ammonia) precipitate all *earths* and *metals,* whether dissolved by volatile or fixed Menstrua, but only in certain states of dilution. For instance, if Sulphate of Alumina be present in the proportion of 4 in 500 in water, it will not be discovered by Potash or Soda. Their very general action prevents the possibility of any accurate conclusion being drawn; further than what may be derived from the whitish or other color of the precipitate, with reference to the presence of metallic admixtures.

39.—*Potash and Soda* expel Ammonia, which may be detected by its pungent smell or by its white vapors, with the moistened stopper of the Muriatic Acid bottle. Carbonates of Potash and Soda have a similar effect.

40.—*Ammonia,* besides precipitating the earths and metallic Salts, gives a blue color where Copper and Nickel are present. Carbonate of Ammonia the same, with the exception of Magnesia. But if it be added to a solution till no further precipitate ensues, and the liquid filtered and raised to a temperature of near the boiling point (212°), and the addition of Ammonia then produce a precipitate, we may infer the presence of Magnesia.

41.—The *Hydrosulphurets* (Sulphides) and *Sulphuretted Hydrogen,* may be detected in water by the metals, Silver, Bismuth or Mercury. For instance, if a little Quicksilver be put in a bottle containing such water, its surface soon acquires a black film, and on shaking the bottle a blackish powder separates from it. Silver and Bismuth the same.

42.—The *Ferro-cyanide of Potassium,* besides precipitating Iron, also precipitates Chloride of Alumina. No conclusion can therefore be drawn

respecting the non-existence of Muriate of Alumina from any process in which this test has previously been used. It will therefore be proper, if a Salt of Alumina be indicated by other tests, to examine the precipitate effected by Ferro-cyanide of Potassium. This may be done by repeatedly boiling it to dryness with Hydrochloric Acid, which takes up the Alumina and leaves the Ferro-cyanide of Iron. From the Hydrochloric solution the Alumina may be precipitated by a solution of Carbonate of Potash.

43.—*Chloride of Calcium* is used to discover the Alkaline Carbonates, which are sometimes found in waters. With all, it forms a precipitate of Carbonate of Lime, soluble of course with effervescence in Hydrochloric Acid. The three Alkalies may be discriminated, Ammonia by its smell and by its precipitating any neutral Salt of Alumina, while it has no action on Magnesian Salts.

Potash by its yellow precipitate, with the Perchloride of Platinum, which does not affect Soda.

To estimate the amount of *Potash or Soda* saturate a solution of either with Sulphuric Acid; 100 grains of pure Sulphuric Acid saturate 121·48 of Potash and 78·32 of Soda.

44.—*Sulphide of Ammonium*, as well as other Sulphides, and water saturated with Sulphuretted Hydrogen, may be employed in detecting *Lead* and *Arsenic*, with the former of which they give a black, and with the latter a yellow, precipitate.

45.—*Vegetable* or *Animal matters* in water are detected by Chlorine solutions or by an infusion of Gallic Acid.

Air diffused in water may be ascertained by boiling, or by the use of the Protosulphate of Iron, as before described for Oxygen, adding to the Protosulphate a few drops of Ammonia, and carrying on the operation so as to exclude the atmosphere. A white precipitate will be formed, passing subsequently to green and to a yellowish orange color.

46.—Waters may be pronounced fit for domestic use when they are fresh, limpid, and free from smell; when they boil Vegetables without affecting their color, and dissolve Soap without leaving curds. This action on Vegetables and Soap is produced by Carbonate of Lime, but it is considered that a certain quantity of Chloride of Sodium and Carbonate of Lime (particularly) is essential in water intended for human consumption, as the Calcareous Salts contribute to the formation of Bone.

47.—The Quantitative Analysis of Mineral Waters must be conducted by evaporation. It requires practised manipulation and good

apparatus, and as it is a business of considerable difficulty, a brief explanation only of the process will be given.

48.—Before Evaporation, the Gases must be expelled and collected. Those must commonly found are *Carbonic Acid, Sulphuretted Hydrogen, Nitrogen, Oxygen,* and in the neighbourhood of Volcanoes, *Sulphurous Acid Gas.* Their expulsion is effected by boiling a glass bottle filled with the Mineral Water in a kettle of brine, immersing it up to the neck. The glass bottle being provided with a glass stopper and heat tube, the expelled Gas escapes by this into a receiver filled with, and inverted in, a Mercury bath—where it is collected together with some of the water itself, which is also driven out by the ebullition. This quantity of water must be deducted from the whole quantity experimented on in calculating.

49.—The amount of *Carbonic Acid Gas* may be determined by introducing a small portion, $\frac{1}{30}$ to $\frac{1}{40}$ the volume of the air, of solution of Potash, (1 part dry Hydrate of Potash to 2 of water) into the Gas contained over Mercury in a graduated glass tube. Agitate this; the amount of the diminution will show the quantity of *Carbonic Acid.*

The unabsorbable residue consists probably of *Oxygen and Nitrogen,* the proportion of which is best learned by the use of Dr. Hope's Eudiometer, or by Liebig's method, using Gallic or Pyrogallic Acid, about $\frac{1}{60}$ to $\frac{1}{80}$ the volume of the air, to absorb the Oxygen. The remainder is of course Nitrogen, as air consists of a mechanical mixture of 79 Nitrogen, and 21 Oxygen, including small quantities of Carbonic Acid and aqueous vapor. Gallic Acid is slow in its operation, requiring an hour or two to act.

50.—If Sulphuretted Hydrogen be present, the separation from Carbonic Acid is more difficult; half fill a vial (graduated) with the mixed Gases, and then expel the rest of the water in the vial by Oxymuriatic Acid Gas (Chlorine) Close the bottle well with a glass stopper and let it remain 24 hours. Then withdraw the stopper under water, when a quantity of water will rush in. Allow it to stand half an hour without agitation. The redundant Chlorine will thus be absorbed, it having a strong affinity for the Hydrogen of Water, forming Hydrochloric Acid and liberating Oxygen, and very little of the Carbonic Acid will disappear. Supposing to 10 cubic inches of the mixed Gases, 10 cubic inches of Chlorine have been added, and that after absorption by standing over water, 5 inches remain. This shows that the mixture consisted of equal parts of Sulphuretted Hydrogen and Carbonic Acid.

51.—When this complicated mixture of four Gases occurs, as in Harrowgate waters, it is advisable to operate on two portions of Gas separately, with a view to determine by the one the quantity of Carbonic Acid and Sulphuretted Hydrogen, and by the other that of Nitrogen and Oxygen. In the latter instance remove both the absorbable Gases by Caustic Potash, and examine the remainder in the manner already directed.

52.—*Nitrogen Gas* sometimes occurs in Mineral Waters almost in an unmixed state. When this happens, the Gas will be known by the characters already described as belonging to it. *Sulphurous Acid Gas* may be detected by its peculiar smell of burning brimstone, and by its discharging the color of an infusion of roses, which has been reddened by the smallest quantity of any Mineral Acid.

53.—Evaporation is perhaps best and most perfectly conducted in unglazed Porcelain vessels at first, and then by removing the water when reduced to about $\frac{1}{10}$ into a smaller glass vessel. In this let it be evaporated to dryness.

The dry mass, when collected and accurately weighed, is to be put into a bottle, and highly rectified Alcohol poured on it to the depth of an inch. After having stood a few hours and been occasionally shaken, pour the whole on a filter, wash it with a little more Alcohol, and dry and weigh the remainder. Call this solution A. (Salts soluble in Alcohol.)

54.—To the undissolved residue add 8 times its weight of cold distilled water; shake the mixture frequently, and after some time filter; ascertaining the loss of weight—Solution B. (Salts soluble in cold Water.)

55.—Boil the residue for a $\frac{1}{4}$ of an hour in about 500 times its weight of water and filter—Solution C (Salts soluble in hot Water.)

56.—The residue, which must be dried and weighed, is no longer soluble in Water or Alcohol. If it has a brown color, denoting the presence of Iron, let it be moistened with water and exposed to the sun's rays for some weeks—(Residue D.)

57.—Solution A. may contain one or all of these Salts: Chlorides of Lime, Magnesia or Barytes, or Nitrates of the same earths. Sometimes also the Alcohol may take up a Sulphate of Iron in which the metal is highly oxidized, as will appear from its reddish brown color.

1*st*. Evaporate to dryness; weigh the residue, add above $\frac{1}{2}$ its weight of strong Sulphuric Acid, and apply a moderate heat. The *Hydrochloric* or *Nitric Acid* will be expelled, and they will be known by their white or orange colored fumes.

2nd. To ascertain whether Lime or Magnesia be the basis of the Salts, continue the moderate heat till no more fumes arise, and let it then be raised to expel the excess of Sulphuric Acid. To the dry mass add twice its weight of distilled water. This will take up the Sulphate of Magnesia and leave the Sulphate of Lime.

3rd. The two Sulphates may be separately decomposed by boiling with three or four times their weight of Carbonate of Potash. The Carbonates of Lime and Magnesia thus obtained, may be separately dissolved in Hydrochloric Acid and evaporated. The weight of the dry Salts will determine how much of each the Alcohol had taken up. Lime and Magnesia may also be separated by the use of Phosphate of Soda.

4th. Barytes, which very rarely occurs, may be precipitated by adding Sulphuric Acid to a portion of the Alcohol solution (*A.*), which has been diluted with 50 or 60 times its bulk of pure water.

58.—*Solution B.* may contain a variety of Salts, the accurate separation of which from each other, is a matter of considerable difficulty.

1st. The Analysis may be attempted by crystallization. If half the solution be evaporated at a heat of about 80° or 90°, and any crystals appear on the surface while hot in the form of a pellicle, let them be separated and dried on bibulous paper. These are Chloride of Soda or Salt.

2nd. The remaining solution, on cooling very gradually, may give crystals distinguishable by their form and other qualities; but when various Salts are contained, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

3rd. Their nature must be examined by means of the re-agents previously given.

4th. Litmus and Turmeric Papers will discover if free or uncombined Acids or Alkalis be present. Potash may be distinguished from Soda by saturation with Sulphuric Acid, evaporation to dryness, and again re-dissolving, the Sulphate of Soda being much more soluble than that of Potash; or by Tartaric Acid or Perchloride of Platinum as before explained.

5th. If neutral Salts be present in the solution, the nature of both the Acid and the base must be ascertained by means of the tests already given.

59.—*Solution C.* contains scarcely anything but Sulphate of Lime.

60.—*Residue D.* is to be digested in Acetic Acid, which takes up Magnesia and Lime; but leaves undissolved Alumina and Peroxide of Iron.

Filter and evaporate the solution to dryness. If it contain Acetate of Lime only, a substance will be obtained, which does not attract moisture from the air. If Magnesia be present the mass will deliquesce. To separate the Lime from the Magnesia proceed as with Solution A.

2nd. The insoluble residue in Acetic Acid may contain Silica, Alumina, and Iron. Dissolve in *Hydrochloric* Acid and filter off the Silica. The Iron may be precipitated by Ferro-cyanide of Potassium or Succinate of Ammonia, and the Alumina by a fixed Alkali or Ammonia.

61.—The Qualitative Analysis of waters may be thus systematized—

1st. The examination of the original water, which should embrace the detection of *Hydrosulphuric Acid*, of *free Carbonic Acid,* and of *organic matter* (by evaporation to dryness and ignition), together with the determination of the reaction to *test papers,* and the rough trial of the *hardness* of the water by the Soap test.

62.—*2nd.* That of the precipitate produced by evaporation which should be examined for the *Carbonates of Lime and Magnesia, Sulphate of Lime, Sesquioxide of Iron, Silicic Acid.*

The precipitate is dissolved in warm dilute Hydrochloric Acid (which should be rinsed round the dish and then poured over the filter, thus obtaining all that is soluble.) The presence of Carbonic Acid will be indicated by effervescence.

The greater part of the solution is evaporated to dryness, and the residue treated with dilute *Hydrochloric Acid.* Insoluble white flakes consist of *Silica.*

The solution, filtered from Silica, is mixed with *Ammonia* in excess. A red brown precipitate is *Sesquioxide of Iron.*

The filtrate is gently heated with *Carbonate of Ammonia.* A precipitate of Carbonate of Lime will be formed if *Lime* be present.

The filtered liquid is mixed with *Phosphate of Soda,* violently agitated, and allowed to stand for 24 hours. A white crystalline precipitate of Phosphate of Magnesia and Ammonia indicates the presence of *Magnesia.*

The remainder of the Hydrochloric solution is tested for *Sulphuric Acid* with *Chloride of Barium.*

63.—*3rd.* The Analysis of the filtrate in which there should be sought all *bases* (lead, &c.) *Silicic Acid, Sulphuric, Hydrochloric, Nitric, Phosphoric, and Carbonic Acids.*

The examination for bases is conducted as usual; *Silicic Acid* will be detected in the examination for bases.

The reaction of the filtrate to *test papers* should be tried. If it be alkaline, *fixed Alkaline Carbonates* are contained in the water.

To one portion of the solution *Chloride of Barium* is added; a white precipitate may consist of *Sulphate, Carbonate,* or *Phosphate of Baryta.* Dilute Hydrochloric Acid is added; Sulphate of Baryta would be left undissolved, indicating the presence of *Sulphuric Acid.* Phosphate and Carbonate of Baryta would be dissolved; the latter with effervescence.

Another portion of the solution is mixed with Nitrate of Silver; the precipitate may consist of Chloride of Silver (white,) Carbonate of Silver (white), or Phosphate of Silver (yellow). Dilute *Nitric Acid* is added. Chloride of Silver would be left undissolved, indicating the presence of *Hydrochloric* Acid.

Another portion is tested for Phosphoric Acid by acidifying slightly with *Acetic Acid,* and adding a single drop of *Perchloride of Iron;* a white precipitate of Phosphate of Peroxide of Iron indicates the presence of *Phosphoric Acid.*

Another portion is mixed with half its bulk of concentrated Sulphuric Acid (perfectly free from Nitric Acid), allowed to become nearly cool, and a crystal of *Sulphate of Iron* dropped into it. After standing for some time at perfect rest, the presence of *Nitric Acid* will be indicated by a brown halo round the crystal.

64.—About 40 oz. or 3 lbs. or a quart of water is enough for a Qualitative Analysis. It should, if possible, be taken in glass stoppered bottles, as with corks Sulphates are soon converted into Sulphides.

The bottles should be quite filled up, and the water analyzed as soon as possible.

65.—As an example of Analysis of a Mineral Water, the following may be taken, and it will serve to exemplify the various tests which have been previously given:—

The water, when recent, did not perceptibly redden *Tincture of Litmus* though the tint was compared with the color of the tincture diluted to a similar extent.

It did not affect the color of *Brazil Wood* or *Turmeric Paper.*

With *Tincture of Galls,* it gave a slight tinge of purple, and ultimately a scanty purplish brown flocculent precipitate, showing the presence of *Iron,* and by the purplish tinge also, the presence of earthy or Alkaline Salts.

66.—The water next day gave no tinge with the *Tincture,* showing the *Iron* to be principally in the state of a *Carbonate.* When the water

was evaporated by a gentle heat, flocculi of *Oxide of Iron* were deposited, and upon being boiled, gave a considerable yellowish white precipitate, indicating *Carbonates.* This precipitate was soluble with considerable effervescence in Nitric Acid.

The water decanted from this precipitate gave no tinge with *Tincture of Galls;* but on boiling it with a few drops of *Nitric Acid,* to peroxidize the Iron which it might contain, the excess of Acid being afterwards neutralized by *Ammonia,* it gave unequivocal traces of *Iron* by a darkish tinge with the *Tincture.* From this it was inferred that the *Iron* was in the state of *Protoxide.*

67.—A portion of this water, after being thus treated, also gave a red tinge with *Sulpho-cyanite of Potash.* With *Ferro-cyanite of Potash* and a drop of *Muriatic Acid,* the water, when recent, gave a whitish precipitate, becoming blue by exposure to the air, indicating *Iron* in the state of *Protoxide.*

68.—With *Lime Water,* the recent water gave a copious flocculent precipitate, the Lime, uniting with the excess of the Carbonic Acid and the whole of the *Carbonates,* falling down together. This precipitate was re-dissolved on adding more of the Mineral Water, which showed a considerable excess of *Carbonic Acid;* and it was also soluble with effervescence in dilute *Acetic Acid.* With the *Bicarbonate of Potash* there was no precipitate, the whole being kept dissolved by the excess of Carbonic Acid.

69.—With *Ammonia* and also with *Potash,* a flocculent white precipitate took place, owing to the abstraction of free Carbonic Acid. With the *Carbonates of Potash, Soda and Ammonia,* there were similar precipitates, but more scanty; they were all soluble in dilute Acetic Acid.

70.—With a solution of *Soap in Alcohol* a great milkiness. With *Acetate of Lead* a considerable milkiness, and a precipitate insoluble in Acetic Acid. With *Oxalate of Ammonia* a considerable precipitate, indicating the presence of *Lime.*

71.—With *Carbonate of Ammonia* and *Phosphate of Soda,* an immediate milkiness and a precipitate after standing indicating *Magnesia,* the precipitate soluble in Acetic Acid. With *Carbonate of Ammonia* or *Phosphate of Soda* separately, no milkiness, after standing for the same length of time.

72.—With *Chloride of Barium* a slight precipitate, insoluble in Hydrochloric Acid, indicating *Sulphuric Acid.* With *Nitrate of Silver,* a copious precipitate, white while secluded from the light, becoming rapidly purple on exposure to light, indicating *Hydrochloric Acid.*

73.—Two ounces of the water evaporated to dryness, gave with *Nitro-muriate of Platinum* slight traces of Potash.

74.—The water, very much concentrated by evaporation, gave with *Starch* and *Sulphuric Acid* no trace of *Iodine.*

75.—From the above indications it was concluded that the water contained *Sulphuric, Hydrochloric* and *Carbonic Acids,* together with *Protoxide of Iron, Lime, Magnesia* and a little *Potash.*

The presence of Alumina was inferred to be incompatible with that of the earthy Carbonates, neither could any be subsequently detected.

76.—The following is given as an example of Analysis to detect *Copper,* where it is supposed to have acted as a poison from being present in food, cooked in imperfectly tinned copper vessels.

77.—The suspected fluid (whether from the stomach or elsewhere) being boiled, is treated or mixed with diluted *Acetic Acid* or *Vinegar,* which dissolves out the *Copper* from among the other matters present.

It is then to be filtered, and any matter left on the filter is to be washed, collected and dried, the washings being of course added to the fluid which first passed through.

78.—The process here divides itself into two, for the *Oxide of Copper* may be left on the filter in the form of an *insoluble Salt,* or it may have passed through in solution.

But it may be observed that very few of the Salts of Copper are insoluble in dilute Acetic Acid, so that if Copper is present at all in a suspected mixture, there are many chances in favor of its being found by the first branch of the Analysis.

79.—The solution is to be examined first, both because it is the more likely quarter in which to find the Copper, and because the Analysis is more easy than that of the solid matter. The solution then is to be treated with *Sulphuretted Hydrogen,* and immediately boiled to expel the excess of Gas.

80.—If a brownish black or even pale brown precipitate is then thrown down, there is a presumption in favor of the existence of *Copper.* If there is no precipitate or brown coloration, there is no Copper in the fluid.

81.—To ascertain precisely the nature of the precipitate, which is some Metallic Sulphuret, the superincumbent fluid, after ebullition and subsidence of the precipitate, is to be cautiously withdrawn, and its place supplied with *water;* and when the washing has been several times repeated in the same manner, the precipitate is to be transferred into a watch glass, or, still better, into a white Porcelain cup, and dried.

82.—It is next to be collected and *incinerated* in a glass or Porcelain vessel to destroy any adhering *vegetable or animal matter.* The last step is to convert the *Sulphuret* into the *Sulphate* by the action of a few drops of *Nitric Acid,* aided by a gentle heat, and then to add an excess of *Ammonia,* either with or without previous filtration, according to the degree of muddiness in the nitrous solution. If *Copper* is present, the usual *deep violet blue tint* will be struck.

83.—*2nd.* If Copper is not detected in the filtered part of the suspected matter, it will be necessary to examine also what remained on the filter. This however will seldom be required, being rendered necessary only by the possibility of the Oxide of Copper having either originally, or after mixture with the suspected matter, assumed the form of an inorganic Salt, insoluble in water or Acetic Acid.

84.—The matter on the filter is first to be well *dried* and then *heated to redness* in a crucible, till it be completely *charred.* The *Copper,* which is thus reduced to the *Metallic state,* is next to be treated with *Nitric Acid, diluted* with its weight of *water,* and aided in its action by gentle *heat.* A solution is then procured, which is to be removed by *filtration* and tested with *Ammonia,* and the other liquid tests. Ammonia, added to a saline solution of Copper, will throw down the blue Ammoniuret as before.

CHEMICAL ANALYSIS, QUALITATIVE OF SOILS.

85.—There are different methods of conducting such Analyses, but perhaps as good a plan as any, is to separate the coarser parts in the manner laid down before for mechanical analysis, and examine these separately by the blowpipe, or otherwise as their structure and composition may seem to require; and to direct the chief attention in the first place to the portion soluble in water, and the finely divided or impalpable portion of the insoluble part.

86.—There is reason to believe that the inorganic matter, taken up by plants, so far as it comes from the purely mineral part of the soil, is derived principally from the finely divided portion, and that the nutritive matters, both organic and inorganic, derived from vegetable and animal bodies in the soil, are also supplied most freely from such as are in fine division of parts, intimately mixed with the soil and undergoing decay.

87.—The coarser portions, therefore, are excluded from consideration in the following Analysis. It is only the finely divided matter, sepa-

rated by suspension in water, and the soluble saline ingredients which are considered.

A considerable quantity of soil should, as before stated, be operated on in order to secure a solution containing some portion, at least, of any substances which may be present in the soil, in small quantities only.

88.—A quantity of air dried soil, finely pulverized, is boiled in a flask with as much *distilled water* as will cover it to the depth of an inch or two, in order to dissolve out its saline ingredients. *Boiled* for 20 minutes, and allowed to subside, the supernatant liquor is poured on to a filter, and if the first portions pass through muddy they are returned to the filter till all passes through quite clear, the object being to obtain a clear saline solution. This operation is repeated several times, till every thing soluble is supposed to be dissolved out, and this may be proved by evaporating on Platinum foil a drop or two of the liquid passing from the filter. If a stain be left, saline matter is still passing out in solution; if there be no stain left on the Platinum, the operation is complete. If the soil contain *Gypsum* (Sulphate of Lime) the process is tedious, but it is necessary to dissolve it out, both because it is soluble in water and for simplifying the other parts of the process.

89.—The whole of the liquor collected should now be concentrated by *evaporation*, taking care not to proceed so far as to cause a deposit.

If the solution by a dark color indicate the presence of much *organic matter*, this should be destroyed before proceeding with the testing. *Evaporate* therefore in a Porcelain, or better, a Platinum capsule to perfect dryness, and then *ignite*, by heating the crucible to incipient redness till all *organic matter* is burnt off, and the contents lose their blackness. It is to be kept in mind, however, that if the solution contained volatile substances, such as *Nitric Acid* or *Ammoniacal* Salts, they are entirely dissipated in this process, and must be tested for in a separate portion of the solution, not evaporated to dryness and ignited. It is also to be observed, that it is better to keep the heat as low as possible during the burning off of the organic matter, to avoid as far as it can be done the loss of *Chlorides*, which are almost invariably present, and are liable to be volatilized at high temperatures. If desirable therefore the organic matter may be estimated separately altogether.

90.—After the organic matter is destroyed, the residue is treated with dilute *Nitric Acid*, and if a small portion of insoluble matter remain it is *Silica* ($Si\ O_2$) and may be filtered off. The Acid solution is now neutralized carefully with *Ammonia*, proving its Acid with *Litmus*, or Alkaline condition with *Turmeric* Paper, and when neutral, is ready for

testing—for which purpose, and for the application of each re-agent, any small and convenient amount of fluid may be taken at a time, the Analysis being merely *Qualitative.*

91.—*Nitrates.*—If, on evaporation and ignition, deflagration should take place during the combustion of the dry residue, it is a proof of the probable presence of *Nitrates,* which may, however, be better proved or confirmed by adding to a portion of the dried residue, *Sulphuric Acid,* and solution of green *Protosulphate of Iron,* when the solution assumes a brown tint, more or less deep according to the quantity of *Nitric Oxide* evolved.

92.—*Ammonia.*—To a small portion of the solution in a test tube *Potash* is added (or solution of Caustic Potash) and the tube heated. If present in any quantity, the smell will betray it; if not, the white fumes arising at the mouth of the tube when a glass rod moistened with *Hydrochloric Acid* is held there, will sufficiently do so.

Or *Grey Litmus* Paper held in the mouth of the tube will become blue, subsequently recovering its color on withdrawal, or on application of gentle heat.

93.—*Sulphuric Acid.*—To a portion of the solution a few drops of *Nitric Acid* are added, in order to prevent the interference of any existing Carbonates with the action of the test next to be added, *viz., Nitrate of Barytes;* on the addition of which to the solution (still remaining clear), if a white precipitate is formed (Sulphate of Barytes), the presence of *Sulphuric Acid* is indicated.

94.—*Chlorine or Hydrochloric Acid.*—A few drops of *Nitric Acid* are added as before to a fresh portion of solution, and then solution of *Nitrate of Silver.* If Chlorine is present, a white curdy precipitate (*Chloride of Silver*) is immediately formed.

This becomes dark on exposure to light; is insoluble in Nitric Acid, soluble in Ammonia. Chlorides are very rarely absent. Chloride of Sodium (Salt) being, for instance, so common an ingredient; but it should be observed that, after the addition of Nitrate of Silver, a solution in which a white haze was barely perceptible at the time will become dark on exposure to light if organic matter is present.

95.—*Carbonic Acid.*—If the solution has given an *Alkaline reaction,* the presence of *Carbonic Acid* may be inferred. If the quantity of *Carbonates* is considerable, and this is very rarely the case, effervescence will take place, when a portion of the concentrated solution is poured into a glass containing Hydrochloric Acid. When the quantity of Carbonates is *small,* no effervescence is perceptible, the Carbonic

Acid being retained in solution. *Lime Water* added, also causes a white precipitate with the Carbonates, of *Carbonate of Lime*, soluble in Acids.

96.—Several of the substances next to be tested for might be easily detected by simple operations of re-agents on separate portions of the solution; but as some cannot be detected till after the removal of others, it becomes necessary to follow a particular order; taking those first whose removal is required for the detection of those that follow, using also a considerable portion of the solution, and that freed from organic matter.

97.—If the previous examination have shown more than a *trace* of *Sulphuric Acid*, as much *Chloride of Barium* is added as is sufficient to precipitate all the *Sulphuric Acid*, and no more, and the *Sulphate of Baryta* is separated by filtration.

98.—To the filtrate, *Ammonia* in excess is added, and from the appearance of the precipitate some information will be obtained regarding the kind of bases present. If the precipitate is dark brown, *Peroxide of Iron* is present; and if on exposure to the air, the color becomes darker, it is owing to the presence of *Manganese*. If the precipitate is white and gelatinous, it is due to *Alumina* or *Magnesia*, or both; but it may have a color more or less deep when all the four are present.

99.—To the solution containing this precipitate *Hydrochloric Acid* is added to re-dissolve it, and on the addition again of *Ammonia* in *excess* the *Magnesia* and *Oxide of Manganese* remain in solution, but the *Peroxide of Iron* and *Alumina* are precipitated. *Filter* quickly; *wash* the precipitate on the filter with the wash bottle and distilled water. Remove the filtrate; when this is thoroughly done, and placing another glass in its place below the filter paper, *receive therein the precipitate* dissolved in *Hydrochloric Acid* poured upon it.

100.—To the Acid solution thus obtained, *Caustic Potash* is added in excess, which has the property of dissolving *Alumina*. The *Peroxide of Iron* is consequently left. Now add *water*, lest the Caustic Alkali should destroy the filter paper and separate off the *Peroxide of Iron*.

101.—To the filtrate (Alkaline from Potash) *Hydrochloric Acid* is added till it is neutral, as proved by test papers. *Ammonia* being now again added, the *Alumina* is precipitated as it was before by this re-agent; now in the form of a white gelatinous Hydrate.

Should *Phosphates* exist, as is very likely, both the Peroxide of Iron and Alumina will contain Phosphoric Acid. This however in a Qualitative Analysis is of no importance, where the object is merely to as-

certain what bodies are present; as a separate process for detecting Phosphoric Acid must be had recourse to.

102.—*Manganese.*—To the solution (Alkaline from the use of Ammonia to precipitate the Alumina) *Hydrochloric Acid* is added till neutral, after which, on the addition of *Sulphide of Ammonium, Sulphuret of Manganese* falls as a flesh-colored precipitate, which, if in small quantity, may not be apparent till it has had time to settle.

103.—*Lime.*—The solution filtered from Sulphuret of Manganese is acidulated with *Hydrochloric Acid*, and *heated* till it ceases to smell of *Sulphuretted Hydrogen,* arising from the Sulphide of Ammonium. If after this it appear muddy, it arises from precipitated *Sulphur*, and it must be freed from this by *filtration.* The solution is then rendered in the feeblest degree Alkaline by Ammonia, and, *Oxalate of Ammonia* being added, it precipitates the white *Oxalate of Lime,* either immediately or after standing some time. This precipitate is liable to run through the filter paper, hence any attempt to filter before it has stood for some hours in a warm place, will be unsuccessful.

104.—*Magnesia.*—The filtrate is carefully *evaporated* to dryness in a Porcelain or Platinum capsule, slowly, also *ignited* to drive off volatile substances (as *Ammonia.)* The residue is dissolved in *water*, and if anything insoluble remains, it may be taken up by a few drops of Hydrochloric Acid and added to the aqueous solution. Pure *Red Oxide* (Nitric Oxide) of *Mercury* (red precipitate free from Nitric Acid and all basic impurities) is added to the solution, and the whole is *evaporated* to dryness. On treating the dry mass with *water, Magnesia* and the excess of Oxide of Mercury remain undissolved (Chlorides of Potassium and Soda, alone remaining in solution.) *Filter, wash* the precipitate, and *ignite* to drive off the Oxide of Mercury. The white powder which remains is *Magnesia.* Or Magnesia may be separated by the use of Phosphate of Soda, as shown at page 154 and elsewhere.

105.—*Potash* and *Soda*—The solution filtered from Magnesia is again *evaporated* and *ignited.* A small portion of the saline mass is tested on *Platinum wire* in the *blowpipe* flame for *Soda* which, if present, would impart its characteristic *yellow color.* To test for *Potash,* re-dissolve the residue in a *small* quantity of *water*, and add a strong aqueous solution of *Tartaric Acid.* If Potash be there, which it very generally is in soils, a crystalline precipitate, the *Bitartrate of Potash,* is formed, or add the *Perchloride of Platinum* and a yellow precipitate, the *Chloride of Potassium and Platinum,* is produced, the formation of which is aided by the presence of free Hydrochloric Acid in the form of a previous addition of a few drops.

106.—*Soda* may also be precipitated in the moist way from the solution filtered from Bitartrate of Potash, by first neutralising it with pure *Caustic Potash*, and again *filtering* it quite free from Bitartrate, after which if solution of *Antimoniate of Potash* is added, a crystalline precipitate, *Antimoniate of Soda*, very similar to Bitartrate of Potash, is produced.

107.—*Phosphoric Acid*.—This ingredient of soils is of so much importance, that, although frequently presenting merely traces of its appearance in the soluble saline matter, it should be carefully searched for. Taking therefore a separate portion of the solution from which *organic matter* has been expelled, a few drops of *Perchloride of Iron* are added to it, if Peroxide of Iron and Alumina are known by the previous tests to be present in small quantity only, but not otherwise. *Ammonia* is next added in *excess* to the liquid contained in a tall narrow test glass, the better to observe the precipitate. When the precipitate has thoroughly subsided, the supernatant fluid should be poured off, or drawn off by syphon, or sucked off by a sucker or pipe (vide page 68), and distilled water again poured on to wash it clean. When this point has been attained, and the wash water as completely removed as possible, the precipitate is digested in strong *Acetic Acid*. If any portion of the precipitate remain undissolved, *Phosphoric Acid* is present. This may be confirmed by dissolving it by saturation with *Soda* and testing with a salt of *Lead*, *Lime* or *Baryta*, when a white precipitate should be formed of the *insoluble Phosphate* of the *re-agent* used.

108.—Other foreign substances, as *Copper*, *Baryta*, &c., may be tested for with their own appropriate re-agents, and every conclusion being carefully noted down on a slate at the time, the operator will then be able to lay down a plan for proceeding with his Quantitative Analysis, in which all his attention will be given to the estimation of such substances as are now known to be the chief ones present, and useless labour, in the search after absent ones, avoided.

QUANTITATIVE AGRICULTURAL ANALYSIS.

109.—In the Quantitative Analysis there will be two portions of the soil to deal with.—*First*, that which is *soluble* in *water*. *Secondly*, the impalpable portion, which is *insoluble* in *water*.

1ST OF THE SOLUBLE PORTION IN WATER.

110.—A saline solution should be prepared from a considerable portion of the soil, ½ to 2 pounds, and in preparing, care is to be taken that every thing soluble is taken up, and that no clay or finely divided solid matter passes through the filter.

The *amount* of *soluble matter* is determined by *evaporation,* adding successive portions of the liquid as the first ones are evaporated, until nothing remains in the Porcelain (or Platinum) crucible, but a perfectly *dry residuum.* Small portions of very volatile matter may escape, but the organic matter present would not at a lower temperature (than 300° Fahrenheit) be sufficiently dry.

111.—*Organic Matter—Nitrates and Ammoniacal Salts.*—These substances, the presence of which will have been previously ascertained, are generally estimated together, but it is not often that Nitrates or Ammoniacal Salts will be found in appreciable quantity.

The crucible, containing the *dry weighed saline matter* is *heated* to incipient *redness,* and kept so till all *organic matter* is burnt away, which is ascertained by the heated mass becoming light in color.

The loss of weight is reckoned as *organic* and *volatile matter.*

In the subsequent processes, it will frequently be necessary to deduct the weight of the ashes of the filter through which a solution has been passed. Hence the necessity of using Griffin's or other prepared circular filter papers, by burning one of which till reduced to ashes, the weight necessary to deduct for such ashes may be known. When it is desired to ignite the filter paper and precipitate, as much of the latter as possible is detached into a crucible from the paper, by gently crumpling the sides of it; then the filter paper, with the remainder of the precipitate on it, being folded up, is held by a pair of forceps in the flame, and the ashes allowed to drop into the crucible, where it is finally ignited till all trace of Carbon is burnt away. It will expedite matters to blow away when burnt, such unimportant parts of the filter paper as hold no precipitate on them.

112.—*Silica.*—After weighing the residue from which organic matter has been burnt away, it must be treated with a few drops of *Nitric Acid* (NO_5,) and then with *Water* (HO) *heat* being at the same time applied, when if any thing remains undissolved it is *Silica* ($Si\ O_2$) and is to be separated by filtration, washed, dried, ignited, and the weight of filter ashes subtracted.

113.—The filtrate must now be *divided* into separate and *equal portions* according to circumstances (say in the present instance 3), either by accurate weighing or measuring while liquid, or by evaporating to dryness, and then dividing and weighing.

114.—*Sulphuric Acid.*—To one of the portions (slightly Acid from the presence of a little free Nitric Acid) solution of *Nitrate of Baryta* ($Ba.\ NO_5$,) is added as long as a precipitate falls. Gentle *heat* is applied, and the precipitate, after being allowed time to settle, is filtered

off, washed, dried and ignited, but with heat no more than is necessary for the complete combustion of the papers. The weight of the *Sulphate of Barytes* (*Ba* SO_3) deducting filter ashes, is then ascertained, and being multiplied by ·34332, gives the weight of *Sulphuric Acid* (SO_3.)

115.—*Chlorine* (*Cl*).—To the filtrate, solution of *Nitrate of Silver* (*Ag* NO_5) is added as long as a precipitate falls; to facilitate the filtration, the whole is boiled for a few minutes and then filtered, washed, and dried. Having been carefully removed from the filter paper, the Chloride of Silver (*Ag Cl*) is fused in a small Porcelain capsule and weighed, the filter paper having been burnt to ashes on the lid of the crucible, and its ashes added to the Chloride. The total weight of fused Chloride (deducting filter ash) multiplied by ·24695, gives the weight of *Chlorine* (*Cl*) found.

116.—*Oxide of Iron*, (*Fe O*)—The filtrate may require to be freed from some portion of the two previously added re-agents, Nitrate of Baryta and Nitrate of Silver, remaining in it in excess, for which purpose a little Hydrochloric Acid (*H Cl*) is added to remove the Silver, and a little Sulphuric Acid to remove the Baryta. The mixture is heated, the precipitates separated by filtration, and the filter washed free from the solution. *Ammonia* ($N\ H_3$) is now added to neutralize the free Acid (Nitric)) whereby as much Ammoniacal Salt (Nitrate of Ammonia) is generated, as prevents the precipitation of Manganese and Magnesia. *Ammonia* is now added in *excess*, and throws down *Oxide of Iron* (*Fe O*) and *Alumina* ($Al_2\ O_3$.)

The precipitate is collected on a filter, during which it is well to exclude air by a glass plate laid over the top of the glass filter, and weighed. It is then *dissolved* off the paper by *Muriatic Acid* (*HCl*) and the paper washed clean with dilute Acid. Both bases are thrown down by *Caustic Potash* (*KO.*) and *Alumina* re-dissolved by excess added of *Potash*. The *Oxide of Iron* is then filtered off, washed, dried, and ignited, with free access of air, and weighed.

117.—*Alumina* —To the Alkaline filtrate, *Hydrochloric Acid* is added till it is neutral or feebly acid, and then solution of *Carbonate of Ammonia* ($NH_4O.\ CO_2$) whereby the *Alumina* is thrown down, but not entirely free from Potash. The precipitate is filtered off and washed, again dissolved off the paper with Hydrochloric Acid, the filter paper well washed, and the *Alumina* again precipitated by *Carbonate of Ammonia*, and well washed on a filter. The *Alumina* is now pure, and is to be thoroughly dried, heated to whiteness, weighed, and the weight of filter ashes deducted.

In many cases the quantities of Oxide of Iron and Alumina are so small extracted by *water* from the soil, that they may be estimated together.

118.—*Lime* (*Ca. O.*)—To the Alkaline filtrate from the Oxide of Iron and Alumina *Oxalate of Ammonia* (NH_4 $\bar{O}$.) is added, whereby the Lime is precipitated as *Oxalate of Lime* (*Ca. O.*)

After standing in a warm place for 12 hours, the precipitate is separated by filtration, washed, dried, ignited and estimated with the precautions previously mentioned. After deducting the weight of filter ash, the weight of *Carbonate of Lime* (*Ca O.* Co_2) multiplied by ·56657, gives the weight of *Lime* present.

119.—*Oxide of Manganese.*—To the filtrate from the Oxalate of Lime, *Sulphide of Ammonium* (NH_4S.) is added, whereby *Sulphuret of Manganese* is precipitated. The precipitate is separated by filtration and washed with water, to which a little of the re-agent has been added. It is while still moist dissolved off the paper by Hydrochloric Acid, and the paper washed till the water that passes through ceases to give an Acid re-action. If the solution smell of Sulphuretted Hydrogen, it is boiled till it ceases to do so, and any deposit of Sulphur is separated by filtration. To this Acid solution, placed in a small Porcelain evaporating basin, solution of *Carbonate of Potash* (*KO.* CO_2) is added in excess, and the whole is evaporated to dryness, but carefully, to avoid spurting. Hot water is next added, by which the soluble parts are taken up, and insoluble *Carbonate of Manganese* remains. This precipitate is collected on a weighed filter, washed, dried, and ignited in an open Porcelain or Platinum crucible at a full red heat, whereby it is converted into red *Oxide of Manganese*. It is then weighed, and the weight (less filter ashes) multiplied by ·93049, gives the weight of *Protoxide of Manganese* present.

120.—SECOND PORTION OF SOLUTION.

Magnesia is most readily separated from the Alkalies by the method of Berzelius, but for this purpose its compounds must exist as *Chlorides*. Hence, if Sulphuric Acid is present, it is to be removed by adding just as much Chloride of Barium (*Ba. Cl.*) as is necessary to precipitate the whole Sulphuric Acid present and no more; and this is effected by using the re-agent pretty dilute, and adding but a little at a time, particularly towards the close. An excess of Chloride of Barium is to be avoided, from the trouble it gives to separate it without the use of Sulphuric Acid.

121.—The bases present, except Magnesia and the Alkalies, are next removed, and by the processes already given, but as much in mass as

possible; thus, in separating the foregoing bases for estimation, every precaution has been recommended to be taken to ensure their purity and accurate separation; now, however, it is desirable to cause them to fall together, in order to shorten the process and save trouble; but in doing this, no step is to be taken that would risk the loss of a particle of Magnesia or the Alkalies.

122.—After the separation of the bases already treated of, the solution, containing the *Magnesian* and *Alkaline Chlorides*, is concentrated by evaporation and transferred to a crucible, in which it is gradually heated to dull redness to drive off all volatile matter.

The Chlorides are now dissolved in a small quantity of water, and if a portion of the Magnesia remain insoluble from the loss of Acid, it is taken up by a drop or two of Hydrochloric Acid, and added to the rest. Excess of pure *red Oxide of Mercury* is next mixed with the solution, and the whole is evaporated to dryness. *Water* is poured on the dry mass, and after being well stirred and gently heated, it is filtered, washed till Chlorine cannot be detected in the water that passes through, but not longer, for Magnesia is not entirely insoluble. The filter, containing the Magnesia and excess of Oxide of Mercury, is dried and ignited, to volatilize the latter and burn the paper. The remainder, deducting filter ash, is *Magnesia.*

For this method may however be substituted that of examination with the Phosphate of Soda. The solution is mixed with as much Chloride of Ammonium as will prevent precipitation by Ammonia, an excess of the latter is then added, and afterwards a slight excess of Phosphate of Soda. The mixture is well shaken up or stirred with a glass rod, which should not touch the sides of the beaker, and allowed to stand for at least 12 hours. The precipitate (Phosphate of Magnesia and Ammonia,) contains 35·7 per cent. of Magnesia.

123.—*Potash and Soda.*—The filtrate from the Magnesia is now evaporated to dryness and ignited to drive off the Mercurial Salt; but as the Alkaline Chlorides cannot be very highly heated without loss, nothing beyond a dull red is admissible. The mixed *Chlorides of Potassium and Sodium* are now weighed, and in many cases it is unnecessary to do more than ascertain the weight of the two together without separating them. If however it be desired to separate them, it may be done as follows. They are mixed with 3.75 their weight of crystallized *Platino-bichloride of Sodium.* The mixture is dissolved in a very small quantity of water, and evaporated at a low heat to dryness. On the dry mass is poured *Alcohol* (*Sp. Grav* ·896) which

takes up everything soluble, leaving *Platino-bichloride of Potassium* undissolved. This is filtered off and washed again with *Alcohol*, after which it is exposed to a gentle heat, till it ceases to lose weight. The weight of this Salt multiplied by ·19307, gives the weight of *Potash* present, or if multiplied by ·30535, it gives the weight of *Chloride of Potassium*.

124.—The amount of *Soda* is estimated by *subtracting* from the *total weight* of the mixed *Chlorides*, before precipitation of the Potash, the weight just ascertained of *Chloride of Potassium*. This gives the quantity present of *Chloride of Sodium*, which multiplied by ·53303, gives the weight of *Soda* present.

125.—THIRD PORTION OF SOLUTION.

Phosphoric Acid is best separated by the method of Schulze, already mentioned. A separate portion of saline matter or saline solution is employed, and in quantity sufficient to afford results capable of being weighed. If Iron has been found in the previous examination, no addition of it may be requisite, but merely to boil the solution with a few drops of Nitric Acid (NO_5) to secure the peroxidation of the Iron.

If no Iron has been found, or only traces, a little *Acetate of Peroxide of Iron* is added. *Ammonia* is next added in excess, and the precipitate, after being well washed, is *digested* in *Acetic Acid*, whereby everything is dissolved except the *Phosphates* of *Iron and Alumina*, these Phosphates are washed, dried, ignited, and weighed.

126.—The mixed Phosphates are then digested in *Caustic Potash*, which dissolves the *Phosphate of Alumina*, and the greater part of the Phosphoric Acid of the Phosphate of Iron. After dilution, the *Peroxide of Iron* is filtered off and washed, but as it still retains Phosphoric Acid (PO_5) it is dissolved off the paper by Hydrochloric Acid, and the filter washed free from Acid. The Acid Solution is neutralized by *Ammonia*, and *Sulphide of Ammonium* added, by which the *Iron* is precipitated as *Sulphuret* or Sulphide. The whole is gently heated for some time, to promote the entire subsidence of the Sulphuret, which is known to be effected when the supernatant liquor is yellow not green. The Sulphuret is now collected on a filter and washed with water containing a little Sulphide of Ammonium.

When the washing is completed, the Sulphuret while still moist is dissolved off the paper with *Hydrochloric Acid* and the paper washed clean. The Acid solution is now *heated* till it loses all smell of *Sulphuretted Hydrogen* (*HS.*), filtered to separate Sulphur, and the paper washed clean. A few drops of *Nitric Acid* are now added to the

filtered solution, and it is boiled to peroxidize the Iron. *Ammonia* is next added in excess, whereby *Peroxide of Iron* is now precipitated pure. The whole is heated to promote the separation of the precipitate, after which it is collected on a filter, washed, dried, ignited, with free access of air and weighed. The weight of filter ash being deducted, the exact weight of *Peroxide of Iron* remains.

127.—The *Phosphate of Alumina* dissolved by the Potash, next requires to be treated so as to separate and estimate the Alumina. For this purpose solution of *Silicate of Potash* is added, to the Alkaline solution, it is diluted, and the whole boiled to promote the separation of *Silicate of Alumina.* The liquid is decanted off, and the precipitate thoroughly washed. It is then treated with Hydrochloric Acid, and cautiously evaporated to perfect dryness, whereby the *Silica* is converted into the *insoluble* form. The dry residue is moistened with a little Hydrochloric Acid, and after standing for some time, the *soluble* part is dissolved in *water*, the *insoluble Silica* filtered off and washed. The solution now contains the *Alumina* free from *Phosphoric Acid.* It is precipitated by *Carbonate of Ammonia* (NH_4 $O.$ CO_2) washed, dried, ignited, weighed.

128.—The united weights of *Iron and Alumina* thus found being deducted from the *total weight* of *mixed Phosphates* first ascertained, gives the amount of *Phosphoric Acid* present, and this method of determining its weight by loss, is had recourse to, because, under the circumstances, it is not possible to ascertain it directly with much accuracy.

129. 2ND.—THE IMPALPABLE PORTION INSOLUBLE IN WATER. —The impalpable portion of a fertile soil consists of minerals in fine division of parts, more or less decomposed, mixed with organic matter chiefly vegetable, in a state of decay. The organic matter may and often does demand a separate examination, chiefly with a view to ascertain its condition; whether it is in an inert condition, as is the case with peat, or whether it is undergoing steady though slow decay, or is in any of the numerous and little investigated intermediate states.

Very few accurate data yet exist on which to base such an examination; hence it is usual merely to estimate the amount of *organic matter* or the matter destructible by a *low red heat.*

130.—After destroying the *organic matter,* the residue will generally be found to consist of *Silica* and *Silicates;* of *Carbonates,* as of *Lime and Magnesia,* that existed as such in the soil; of *Peroxide of Iron* and *Alumina* resulting from decomposed Silicates; of a small portion of *Phosphates,* and of the bases that were united with the organic matters.

131.—This residue then (the *1st portion*) is usually treated with cold diluted Hydrochloric Acid, and the *Lime*, and if necessary, the *Magnesia* and *Peroxide of Iron*, estimated.

The portion remaining (*2nd portion*) which will not dissolve in Hydrochloric Acid, is then analyzed by *fusion* with *Alkalies*, which reduces it into a state in which it is capable of forming a *solution* fit for Analysis. In this way, however, the Alkalies cannot be directly determined owing to the use of Carbonate of Potash, and a separate process is necessary for estimating Magnesia and the Alkalies; and when the operator possesses the means, the best method is by *Hydrofluoric Acid*, which presents the only other method, besides fusion with Alkalies, of acting upon the Silica of the soil.

132.—Of the *1st portion, Soluble* in *Hydrochloric Acid.*

The *organic* matter having been *burnt* off from a portion, say 50 *grains* of soil, the contents of the crucible are transferred to a Porcelain evaporating basin, and treated in the cold with *Hydrochloric Acid*, diluted with three or four times its bulk of water, being frequently stirred with a glass rod and allowed to stand 10 or 12 hours, *filtered* and the residue washed free from Acid, dried, ignited and weighed. The loss of weight shows how much the Hydrochloric Acid has taken up, and the whole quantity of dried *residuum* is put aside to be treated by *fusion* with Alkalies as hereafter described.

133.—The acid solution or filtrate is concentrated by *evaporation* and neutralized with *Ammonia*, and on adding a slight excess of the Alkali, a precipitate is thrown down, consisting chiefly of *Peroxide of Iron, Alumina* and *Phosphoric Acid.* The precipitate is collected on a filter (protected from the air by a plate of glass) and washed.

134.—*Lime.*—If now the only thing to be estimated is *Lime*, it is done by adding *Oxalate of Ammonia* to the filtrate, and proceeding as directed in the first form of Chemical Analysis given at page 54, but if otherwise, the resulting filtrate, after this being done, is reserved to be joined to another, and examined for Manganese and Magnesia.

If Phosphoric Acid is present, it exists of course in the precipitate thrown down as above by Ammonia, and must be estimated by digesting the precipitate in Acetic Acid ($\overline{A}$), *vide* para. 125. The solution is then evaporated to dryness in a Platinum capsule and ignited at a dull red heat. The *residuum* is transferred to a Porcelain capsule, dissolved in Hydrochloric Acid, and put aside to be mixed with the Hydrochloric Acid solution obtained after fusion of the insoluble residue with Alkalies as follows, to be examined for Phosphoric Acid.

135.—Of the *2nd Portion, Insoluble* in *Hydrochloric Acid*,

The Silicates, insoluble in cold Muriatic Acid, may, if necessary, be further extracted, if possible, by the action of hot concentrated Hydrochloric Acid, or even Nitro-hydrochloric, but if not much is to be gained by this, it is as well to fuse them at once in the furnace with Alkalis.

136.—The mineral matter, in a finely *pulverized* or impalpable state, is transferred to a crucible, and intimately mixed with *three or four times* its weight of dry powdered *Carbonate of Potash*. The crucible is covered with its lid, is heated gradually up to a powerful red heat, and kept so for an hour, or till *complete fusion* is effected. The ignition may be effected most conveniently in a *Gas furnace*, but failing this a *coal* or a *charcoal fire*, or one made of the two materials mixed, will answer the purpose.

137.—When the ignition is finished, and the mass of fused matter or glass has somewhat cooled, *Water* is introduced, and under its influence the solid matter *dissolves*, the process being aided by the use of a glass rod, and if necessary by *dilute Muriatic Acid*, to wash out and dissolve the last most firmly adhering portions. If the crucible be Platinum, it should be protected from the action of the fuel by a fire-clay crucible case, and after ignition the fused mass should be transferred by pressing the sides, by washing with water, and finally dilute Acid, to a Porcelain vessel. Hydrochloric Acid might be employed from the first, but that loss by too violent effervescence is very liable to take place, and that when Manganese is present, Chlorine would be evolved, which would act on the Platinum vessel.

Finally, Hydrochloric Acid is added carefully till a decided Acid reaction is obtained. The capsule is then set to digest for some time on the warm sand-bath. The *Silica* now appears as a *light flocky sediment*, but a portion of it, and in some cases even the whole, exists in a state of solution. It is in fact still in its *soluble* form.

138.—The decomposition is known to be effected completely when on stirring with a glass rod, no fine *gritty matter* is felt in the bottom of the capsule; should the decomposition prove incomplete, the flocks of Silica are floated off in the solution, and the undecomposed portion being washed, is dried and again mixed with a fresh portion of Carbonate of Potash, to be subjected a second time to ignition, and the fused mass is dissolved out and treated as before.

139.—The solution is now *evaporated* to perfect dryness, whereby the *Silica* is brought to the *insoluble form*. The dry mass is then uniformly moistened with a few drops of strong *Hydrochloric Acid*, and

left to stand in the cold for some time, *water* added, which dissolves everything but the *Silica*, and the latter collected on a filter, *washed, dried, ignited and weighed.*

140.—The acid solution is then mixed with that obtained from the former process with the portion soluble in Hydrochloric Acid, and the Analysis proceeded with as follows.

To the conjoined Hydrochloric Acid solutions, *Ammonia* is added to neutralize and then in *excess* to throw down *Peroxide of Iron and Alumina*, care being taken that as much Ammoniacal Salt is present as to prevent, so far as it can be done, the precipitation of Manganese and Magnesia. The precipitate is collected on a filter protected from the air and quickly washed. The precipitate of Peroxide of Iron and Alumina, even when a considerable quantity of Ammoniacal Salt is present, falls accompanied by small quantities of Oxide of Manganese and Magnesia which, if the operation is to be an exact one, must be separated.

141.—*Alumina.*—The precipitate by Ammonia is dissolved off the filter by *Hydrochloric Acid*, and the paper washed clean. To the solution *Caustic Potash* is added in excess and the whole boiled. The *Alumina* is thus taken up. The *Iron, Manganese* and *Magnesia* left as precipitate. The solution is diluted with water, filtered, and the precipitate washed till no Alkali can be detected in the water. The *Alumina* is precipitated as before directed, by *Carbonate of Ammonia.*

142.—The precipitate is now dissolved off the filter by *Hydrochloric Acid*, and excess of Hydrochloric Acid is employed, in order that, on the addition of Ammonia, enough of Sal-Ammoniac may be generated to render the subsequent separation of the Iron from the Manganese safe. To the acid solution *Ammonia* is added cautiously, and that there may be no danger of supersaturation a very dilute solution of Ammonia is used towards the close; and it is also expedient to reserve the last washings of the filter, which, being but very feebly acid, are to be added to the rest of the solution at the time that the very dilute Ammonia is in use. It is known that exactly enough of Ammonia has been added, when a slight precipitate of Peroxide of Iron, produced by the last added drop of dilute Ammonia, does not quite dissolve when the solution is gently heated. This point attained, the Iron is precipitated by neutral Succinate of Ammonia, or *Ferro-cyanide of Potassium*, and the solution is allowed to stand till it is completely cold.

The precipitate is carefully washed with cold water after being collected on a filter. The *filtrate* contains the small quantities of

Manganese and *Magnesia*, and is reserved to be treated along with the solution previously set aside which contains these bases.

143.—The filter is then dried and ignited, air being admitted freely into the Platinum crucible to consume the remains of the filter paper. When the crucible is cold enough, it is weighed, and the weight of filter ash deducted, that of *Peroxide of Iron* remains.

When the ignition is carefully conducted, there is little danger of any portion of Peroxide of Iron being reduced from the state of Oxide to the metallic state; if however it so happen, and the residuum proves attractable by the magnet, it is to be re-dissolved in Muriatic Acid, and boiled with a drop or two of Nitric Acid. Peroxide of Iron is then thrown down by Ammonia and estimated a second time.

144.—*Lime.*—The solution filtered from Peroxide of Iron and Alumina is rendered feebly Alkaline, and Lime precipitated by *Oxalate of Ammonia,* and then estimated as *Carbonate* as before described. This Lime must be described in the table of results as existing as *Silicate* in the soil.

145.—*Manganese.*—The filtrate joined to the previously obtained similar filtrate after using Oxalate of Ammonia, is rendered quite neutral by *Hydrochloric Acid* and *Sulphide of Ammonium* added, to precipitate the *Manganese* as Sulphuret, as before described.

146.—*Magnesia* and the *Alkalies.*—The filtrate is acidulated with *Hydrochloric Acid, boiled* to expel *Sulphuretted Hydrogen, filtered* to remove separated *Sulphur, evaporated* to dryness and *ignited* at a low red heat to expel *Ammoniacal Salts.* The *Magnesia* and *Alkalies* are then separated in the same manner as in the Analysis of the soluble saline matters.

147.—*Phosphoric Acid.*—This is best estimated by taking a separate and a larger portion of the impalpable part of the soil, say 500 or 1,000 grains. This is first ignited, to destroy *organic matter,* then treated with *Hydrochloric Acid* to which a little *Nitric Acid* has been added, filtered, and the filter washed. To the filtrate excess of *Ammonia* is added; the precipitate thereby produced is digested in *Acetic Acid,* and the remaining parts of the process conducted as before described.

148.—Should the operator prefer the method of Analysis by *Hydrofluoric Acid* (*H F*) to that by fusion with the Alkalies, the following is the course to be pursued.

The impalpable residue from the Hydrochloric Acid solution is, after being weighed, placed in a pretty large Platinum capsule, set near a ventilator or chimney to carry off fumes, and recently prepared fuming *Hydrofluoric Acid* is poured upon it.

149.—The mixture is well stirred with a Platinum spatula, and *Sulphuric Acid* (SO_3) added. An evolution of gaseous Fluoride of Silicon and Hydrofluoric Acid takes place, and when the heat is raised, excess of Sulphuric Acid escapes. To ensure the escape of the latter, the heat towards the close of the process is gradually raised, till the vessel is heated to incipient redness. The whole is then allowed to cool, and to replace the Acid that has been driven off from some of the bases, the mass is uniformly moistened with *Hydrochloric Acid,* and allowed to stand in the cold for half an hour. The mass is now treated with *Water,* and the whole is warmed. The small quantity of *Silica* present is filtered off and the filter washed free of Acid.

150.—The filtrate is analyzed nearly in the same manner as already pointed out. Free Acid is neutralized by *Ammonia,* a slight excess of which throws down *Iron* and *Alumina,* together with small quantities of *Manganese* and *Magnesia.* These are treated as before described.

Lime is precipitated by *Oxalate of Ammonia.*

Manganese by *Sulphide of Ammonium.*

151.—The filtrate from the last, after being acidulated with *Hydrochloric Acid,* boiled, and filtered, is *evaporated* to dryness and cautiously *ignited.* The residue which consists of *Magnesia* and *Alkaline Sulphates,* must be converted into *Chlorides,* both for the purpose of separating Magnesia by the method already described, and for the separation of the Alkalies from each other.

152.—For this purpose, the Sulphates are dissolved, the solution is warmed, and *Acetate of Baryta* is cautiously added, till all the Sulphuric Acid is precipitated, but excess must be avoided. After the precipitate has subsided, it is collected on a filter and washed clean. To the filtered solution *Hydrochloric Acid* is added, and it is slowly evaporated to dryness, heated to incipient redness, and weighed; after which the separation and estimation of *Magnesia* and the *Alkalies* is proceeded with as described.

153.—Since by this process the Silica cannot be estimated, it is necessary to determine its quantity by fusing a separate portion of dry impalpable matter with Carbonate of Soda.

154.—The student will readily observe, from the foregoing Qualitative and Quantitative Agricultural Analysis, that, although it may not be a very difficult matter to pronounce upon the mere *presence* or otherwise of any Salt or substance in a soil, by the use of a re-agent or test, yet that it is a very different, and a much more complicated and delicate business, when it is required to make a *Quantitative* Analysis,

in which the exact amount of each ingredient is to be ascertained and weighed apart.

155.—Every solution must be most carefully *prepared* in the first place for the addition of the re-agent about to be used. Its Acid, Neutral, or Alkaline state precisely arranged, and after separation by the filter, every precipitate has to be thoroughly washed with distilled water, the washings tested with test papers or other re-agents, to prove that not the minutest portion of the Acid or other contents of the solution remain in it, then dried, and then ignited together with the filter paper, the ashes of which have to be deducted from the weight, which is last of all ascertained.

156.—These however are comparatively simple processes, which every chemical manipulator must be conversant with. It is when Magnesia, Ammonia, Carbonic Acid, Antimony, Tin, and such like have to be separated and ascertained in *quantity*, that complicated apparatus, perfectly pure and fresh re-agents, and very great manipulative skill are required, such as to render it almost impossible to conduct with success an Analysis of this kind, except in a regularly prepared laboratory. Hence it is not to be expected that such could be made by amateurs in India, and certainly not with the degree of accuracy which is demanded at the present day in these matters. Nevertheless, I have thought it as well to give at least the general sketch herein submitted, by the aid of which much may be done, although, if absolute accuracy is demanded, professional aid in this, as in other sciences, should be called in.

157.—The mere perusal of these Analyses, will confirm and increase the analytical knowledge of the student, nor is there any impediment it is hoped to the simpler parts of them being carried out, with a moderate degree of patience, and no very complicated amount of chemical apparatus.

SECTION V.

DETAILED METHOD OF HUMID ANALYSIS WITH ANALYTICAL TABLES.

1.—When the student comes to the actual practice of Humid Analysis himself, it will be necessary that he should have before him a succinct method to pursue, and that he should understand the principles upon which it is based, and this I now propose to give as the concluding Section of Part II. It is the method pursued at the Royal College of Chemistry, London.

2.—Minerals may be divided into 3 classes.

1st.—Those soluble in Water.

2nd.—Those soluble in Hydrochloric or Nitric Acid.

3rd.—Those not soluble in Water or those Acids.

Water is the preferable solvent, but when a Mineral is not soluble in Water, it must be dissolved in Hydrochloric or Nitric Acid, or in the two mixed together (Aqua Regia).

3.—In this manner, the Carbonates, Phosphates, Arseniates, Chromates, and many hydrous and anhydrous Silicates, many Sulphides, Arsenides, and other metallic compounds, are decomposed and rendered soluble in water.

4.—If the solvent used be an Acid, it should be carefully added in small quantities at a time, and heat applied (that of the sand-bath is best) after each addition. The substance should also be reduced to a fine powder.

5.—If by boiling in 10 times its amount of water, a perfect solution be obtained, that solution must be tested in the usual manner. If it dissolve only partially, the insoluble residue should then be tried with boiling Hydrochloric Acid and if it is all thus dissolved, the Analysis may be proceeded with as before. If an insoluble residue remain, a fresh portion of the powdered mineral should be taken, say 20 grains, and boiled in Nitric Acid.

If this fail to dissolve it entirely, Aqua Regia must be tried; that is, Hydrochloric, equal in quantity to the Nitric Acid, may be added to the mixture and the whole boiled.

6.—When it is wished to ascertain roughly how much the solvent may have taken up after boiling, a few drops should be filtered off on to Platinum foil and evaporated.

The amount of residue left on the foil will indicate how much has passed into solution. If this indicate that much has been dissolved, the filtrate should be examined.

7.—The usually occurring substances which are insoluble in Water and Acids are, Gold, Platinum, Tin, Antimony, the Sulphates of Baryta, Strontia, Lime and Lead, the Chlorides of Silver and Lead, Fluoride of Calcium, Silicates, Silica and Sulphur.

8.—If it be Sulphur, it may be detected by its smell when heated. When other substances are present, add to a small portion of the insoluble residue a drop of Sulphide of Ammonium (NH_4S.) If the color remains white, Silver, Lead, and probably Iron, are absent. If the substance be found insoluble in Water or in Acids, the insoluble portion of it should be fused with the Alkalies, Carbonates of Soda and Potash. The portion to be fused being reduced to a fine powder, is mixed with four times its weight of the two above-mentioned Alkalies in equal proportions, and the mixed mass is either fused in a Platinum crucible over a furnace lamp, or in a Porcelain crucible in a charcoal fire. On cooling, the fused mass is boiled with water and filtered.

9.—Some mineral Aluminates nearly infusible in Carbonate of Soda, may be readily decomposed by fusion with a mixture of Carbonate and Borate of Soda, or with anhydrous Bisulphate of Potash. In some cases, as when the Mineral contains Soda, it should be decomposed, by heating it strongly with five times its weight of Carbonate of Baryta.

10.—The filtrate is to be examined for the Acids and Alumina, the residue for the bases.

To one portion of the filtrate add Hydrochloric Acid until the solution is distinctly Acid, evaporate to dryness, and ignite until Acid fumes are no longer evolved. To the dried mass add dilute Hydrochloric Acid and boil; if a residue remains, Silicic Acid is present. To the filtrate from the Silica, add Ammonia in excess, and then warm the solution; if a precipitate is formed it must be due either to Alumina or its Phosphate. After having filtered and washed the precipitate, examine whether it is soluble in Acetic Acid (Phosphate of Alumina is insoluble.)

In the filtrate from the Alumina precipitate, or in the solution which has failed to give a precipitate, test for Phosphoric Acid, by adding Chloride of Ammonium and then Sulphate of Magnesia.

11.—Acidulate another portion with Hydrochloric Acid, and examine for Sulphuric Acid with Chloride of Barium.

12.—Another portion acidulated with Nitric Acid may be tested for Chlorine by Nitrate of Silver, and to detect Fluorine, a portion must be treated with concentrated Sulphuric Acid, as described under the head of Hydrochloric Acid.

13.—The residue to be examined may be dissolved in Hydrochloric Acid and tested in the usual way for the bases.

If it does not completely dissolve, and Lead and Silver are absent, (if present, they would form insoluble precipitates, Chlorides,) it shows that a portion has not been decomposed. When this is so, filter off and examine the filtrate. The insoluble residue must be fused, if the fixed Alkalies Potash and Soda are to be looked for, with Carbonate of Baryta in a Platinum crucible, and so examined.

14.—The presence of fixed Organic matter interferes with the detection of many substances. Thus in the presence of Tartaric Acid, which is a fixed organic Acid, the Oxides of Alumina, Chromium and Iron, and many other Metallic Oxides, are not precipitated by the Alkalies. When an Inorganic Analysis has, therefore, to be performed upon a substance containing organic matter, this last must generally be destroyed before the examination is attempted. This is usually done by ignition in a Porcelain or Platinum crucible.

15.—Metals are generally treated with Nitric Acid, which converts them into soluble Nitrates, oxidizing them, except Gold and Platinum, which are not acted upon by it, and Tin and Antimony, which are converted into insoluble Oxides. If complete solution therefore ensue on treating a metallic alloy with Nitric Acid, these four metals are absent. If a metallic residue remain, Gold and Platinum are indicated, and may be tested for by Protosulphate of Iron and Chloride of Potassium. If a white insoluble substance separates, Tin and Antimony are indicated. Treated with a hot concentrated solution of Tartaric Acid, if it all dissolves, it is Antimony, and Tin is absent. If it does not all dissolve, it is filtered and the filtrate examined for Antimony by Hydrosulphuric Acid, producing in the Tartaric Acid solution to which it has been added, an orange red precipitate. The residue, after being well washed, is examined under the blowpipe with Cyanide of Potassium and Carbonate of Soda on charcoal in the inner flame, for ductile metallic grains of Tin.

16.—For the purposes of precipitation in the course of Humid Analysis, the Metals may be divided into the following classes:—

1st.—Metals yielding Alkalies by Oxidation, as Potassium, Sodium, Ammonium.

2nd.—Metals yielding Alkaline Earths, as Barium, Calcium, Magnesium, Strontium.

3rd.—Metals yielding pure Earths, as Aluminum, Glucinum.

4th.—Metals which decompose Water at a red heat, or which, having a great affinity for Oxygen, are Oxidized quickly when exposed to moisture, as Iron, Cadmium, Zinc, Manganese, Nickel, Cobalt, Tin.

5th.—Metals which do not decompose Water at a red heat, or which have not so great an affinity for Oxygen, as Arsenic, Antimony, Chromium, Lead, Copper, Bismuth.

6th.—Metals which have so little affinity for Oxygen that their Oxides are reduced to the Metallic state by heat, as Mercury, Gold, Silver, Platinum.

17.—If engaged upon a solution, to discover if it contain any of the above substances, we should first discover, by means of test-papers, whether it be Acid, Alkaline, or neutral, and we may then evaporate a drop of the liquid upon Platinum foil, to ascertain whether it contains an Organic or Inorganic substance.

18.—In the former case it is necessary to get rid of all Organic or Carbonaceous matter by ignition, as previously stated, before proceeding with the Analysis.

19.—In the case of a Mineral substance, we may then treat it with Sulphuretted Hydrogen, which produces precipitates with the Metals of the 4th, 5th and 6th classes ; but not of the first three.

20.—The latter three, when treated with Sulphide of Ammonium, will give a precipitate in the case of Metals of the 3rd class, but not with those of the 1st and 2nd.

21.—Lastly Carbonate of Potash may be employed to distinguish the Metals of these two classes (as it precipitates the second, but not the first.)

22.—If Sulphuretted Hydrogen cause a precipitate, we may afterwards employ Ferro-cyanide of Potassium, which gives precipitates of very characteristic colors with several Metals, which are not distinguished from one another by Sulphuretted Hydrogen alone, and lastly, special tests must be used, of which many will be found given herein.

23.—It has been said that Organic matter should always be removed as interfering with Analysis. If analyzing for poison, or where great nicety is desirable, this may be done, in the case of liquid substances, by mixing them with distilled Water, boiling and filtering them, and then by treating the liquid with absolute Alcohol, or a current of Chlorine, and filtering anew.

24.—When operating upon solid matter (as for poison) the Organic matters may be destroyed by, 1st, Nitric Acid or Nitrate of Potash, or 2ndly, Sulphuric Acid, either alone or with the addition of a little Chloride of Lime in order to disengage Chlorine; 3rdly, by a stream of Chlorine; 4thly, by Hydrochloric Acid and Chlorate of Potash.

The solid substance or solution is boiled with concentrated Hydrochloric Acid, to which Chlorate of Potash in powder is added gradually, until the mixture becomes perfectly fluid; the solution is then heated until all free Chlorine is evolved; after which it is diluted with Water and filtered.

25.—It may even be desirable to remove all coloring as well as Organic matter, and for this purpose washed *animal* Charcoal is employed in *small* quantities, for it not only retains the coloring matters, but also a considerable portion of Metallic as well as of other poisons. The Charcoal should therefore be preserved for subsequent testing if it should be thought necessary. In some cases Chlorine or Sulphurous Acid is preferable to Charcoal.

26.—Another and more convenient arrangement perhaps, may be made of the Metals, &c., for the purpose of Geological Analysis, as follows:

First Group.—Ammonia, Potask, Soda.
Second „ Baryta, Strontia, Lime, Magnesia.
Third „ Alumina, Chromium, Iron, Zinc, Manganese, Nickel, Cobalt.
Fourth „ Arsenious Acid, Arsenic Acid, Antimony, Tin, Gold, Platinum.
Fifth „ Bismuth, Cadmium, Copper.
Sixth „ Silver, Mercury, Lead.

27—Hydrochloric Acid is first used, which precipitates the members of the sixth group as Chlorides.

28.—Sulphuretted Hydrogen is then employed to precipitate the fifth and fourth groups.

29.—Then Sulphide of Ammonium to precipitate the members of the third group.

30.—Carbonate of Ammonia to throw down those of the second, (a special test, Arseniate of Ammonia, being employed for the detection of Magnesia.)

31.—And lastly, the first group are separated by the special tests applicable to them individually.

32.—The foregoing is Galloway's method, but a modification of it will be given, with the requisite Tables for working out the details, which may be preferred.

33.—In it the groups and their precipitates are thus arranged:—

First	Group.—Silver, Lead, Mercury, ...		Precipitated by Hydrochloric Acid.
Second	„	Bismuth, Copper, Tin, Cadmium, Antimony, Arsenic, Gold, Platinum, ...	Ditto by Sulphuretted Hydrogen.
Third	„	Iron, Alumina, Chromium, ...	Ditto by Chloride of Ammonium.
Fourth	„	Zinc, Manganese, Nickel, Cobalt,	Ditto by Sulphide of Ammonium.
Fifth	„	Barium, Strontium, Lime (and Magnesia, by a special test, Phosphate of Soda,)...	Ditto by Carbonate of Ammonia
Sixth	„	Potash, Soda, Ammonia, ...	By special tests.

34.—GENERAL ANALYTICAL PROCESS

Designed especially for the Examination of Minerals.

PRELIMINARY EXAMINATION.

The substance is heated upon charcoal with *Na O* CO_2 and *K Cy* (the latter is not generally used, only in cases where *Sn* and *Cu* are especially sought,) in the reducing blowpipe flame, the oxidizing flame being allowed to flow over the charcoal.

35.—If no metal is thus obtained at once, it is advisable to triturate the test specimen and surrounding charcoal particles in an Agate Mortar with a little water, and to wash away the charcoal with water.

Metallic Globules—

Malleable — *Pb, Ag, Cu, Sn*

Brittle — *Bi, Sb*

Metallic scales on trituration *Cu, Sn, Sb.*

Incrustations—

White, *Sb, As, Zn*

Also salts of *Am* and *Hg.*

Yellow or Brown, *Pb, Bi, Cd.*

Garlic odour — *As.*

36.—The substance is added by small portions at a time to a bead of Borax, and heated first in the outer, and then in the inner flame; the color produced in each case being carefully observed, both in the hot and cold bead.

A green bead is obtained in the outer flame; presence of *Cr*, Chromium, (emerald green unchanged in the inner flame;) or *Cu*, blueish green, either disappearing entirely or acquiring a partial opaque red color, in the inner flame.

A reddish yellow bead is obtained in the outer flame; presence of *Fe*, (color either vanishes or fades on cooling and becomes bottle green in

the inner flame); or *Ni*, color vanishes or fades on cooling, and becomes dusky purple or grey, in the inner flame.

A blue bead is obtained in the outer flame; presence of *Co* (color unchanged in inner flame); or *Cu*, greenish blue, either vanishing or becoming opaque red in parts, in inner flame.

37.—A portion of the substance is mixed in a dish with dry $Ca\,O.\,HO$, moistened with a little water and gently heated.

Pungent vapors are evolved, which yield white fumes with HCl, and are alkaline to test papers; presence of $N\,H_3$.

38.—ON THE PROCESS OF SOLUTION.

In very few cases is it necessary to extract minerals with water, since they very seldom yield any notable amount of substance to this menstruum. However, if it be desired to ascertain whether such treatment is requisite in any particular case, a quantity (say about 60 grains) of the finely powdered mineral is boiled for some time with water, and the solution decanted and filtered. By evaporating a drop or two of this filtrate on a watch glass, or on Platinum foil, we shall ascertain whether the solution be fit for Analysis; that is, whether the water has or has not dissolved much of the specimen.

39.—On the other hand, most minerals dissolve to a certain extent in acids, and upon the choice of these depends, in great measure, the easy success of the Analysis.

40.—As a general rule, it is most advantageous to employ concentrated HCl (subsequently treating with water) for the solution of minerals, which consist chiefly of Oxides, Carbonates &c. (*e. g.* Limestones, Ironstones, Spathic Iron Ore, Malachite, &c.) and HO, NO_5 (*concd.*) for such as consist of Arsenides, Sulphides, &c. (*e. g.* the Blendes, Speiss Cobalt, Galena, &c. &c.)

41.—It is advantageous in those cases in which the presence of *Ag* or *Pb* is not suspected, to make use of a mixture of one part of $HO\,NO_5$ with from three to four parts of strong HCl; such a mixture is peculiarly appropriate for the solution of the various pyrites and similar minerals.

42.—GENERAL ANALYTICAL PROCESS.

The Process of Solution (continued.)

In cases where the presence of *Sb* and *Sn* is suspected, the mineral is best dissolved by boiling with concentrated HCl; $HO.\ NO_5$, being added from time to time till all action ceases.

43.—Since it can always be readily ascertained, by the preliminary examination, whether the mineral is an Oxide, a Sulphide, or an Arsenide, or whether it is likely to contain *Sb*, *Sn*, *Ag* or *Pb*, one of the above rules may always be put in practice.

44.—It is not very commonly that any advantage is gained by treating minerals first with *HCl* or *HO. NO*$_5$ alone, and afterwards with Nitro-Hydrochloric Acid; but if *Au*, *Pt*, &c. are to be specially sought, the mineral should be extracted as far as possible with concentrated *HCl*, and the residue boiled with Aqua Regia.

45.—Whenever any mineral is treated with an acid, it is well to boil first with the acid, and then, without pouring off the latter, to dilute with water and boil a second time. The residue is then allowed to subside and the solution filtered. The object of boiling with water is to *remove* any products which might be sparingly soluble in the concentrated acid *e. g. Ba Cl* sparingly soluble in concentrated *HCl*; and *KO. NO*$_5$ sparingly soluble in concentrated *HO NO*$_5$

46.—That portion of the mineral which is not affected by acids, if it be dissolved only to a very slight extent by the latter, or the original mineral, is fused with about four times its weight of a mixture of equal parts of *KO*, *CO*$_2$, and *NaO*, *CO*$_2$ for about an hour, the fused mass when cold is boiled with water till it is entirely disintegrated. The aqueous solution is examined for *Si O*$_2$ *SO*$_3$ and *H F*. The residue is well washed with boiling water and extracted with dilute *HCl*; if the presence of *Ag* or *Pb* be suspected, *HO. NO*$_5$ should be substituted. Any residue insoluble in this acid consists of *Si O*$_2$. The *HCl* solution is evaporated to dryness to separate *Si O*$_2$, re-dissolved in diluted *HCl*, and the solution examined for bases (*vide* Table next page.)

47.—The fusion may in most cases be performed in a Platinum crucible, but if any easily reducible metals (such as give globules before the blowpipe) be present, a Porcelain crucible should be employed; the requisite heat may be applied either from a good Gas burner or from a Coke fire, or, as a last resource, a Charcoal furnace. In either of the last cases the crucible should be enclosed in one of clay, packed with Magnesia before being introduced into the fire.

48.—The above general rules will, in all cases, ultimately lead to the preparation of a solution fit for Analysis, but it often happens that special methods of solution may be discovered, which are much better adapted to the substance in hand (*e. g.* Chrome Iron is most easily decomposed by fusion with *KO. NO*$_5$ and *NaO. CO*$_2$. Tin stone should be fused with *K. Cy*, &c.) but these methods, and the cases in which they may be employed, must be learnt by actual experience.

GENERAL TABLE

For the Analysis of substances, which may contain all the more frequently occurring Bases. To the greater portion of the original solution add HCl in excess and heat gently.

Group 1. Precipitate may contain $Ag\ Cl$, $Hg_2\ Cl$, $Pb\ Cl$, Examine by Table I.

The filtrate (which if As has been detected in the preliminary examination, must now be completely saturated with SO_2 * (Note *a*) and evaporated to expel excess of this latter) is largely diluted with HO completely saturated with HS and gently heated for some minutes.

Group 2. Precipitate may contain PbS, HgS, BiS, CuS, CdS, SnS, SrS_2, SbS_3, SbS_5, AuS_3, AsS_3 $Pt.\ S_2$. Examine by Table II.

The filtrate (wchich must be tested with a little more HS) is mixed with conc. HO,NO_5 and evaporated to dryness on the sand-bath. The residue is heated to redness in the air till all organic matter has burnt off, and is boiled with conc HCl, water added and if necessary the solution filtered (the residue consists usually of SiO_2). To this solution are added $NH_4\ Cl$ and NH_3. The solution heated and rapidly filtered.

Group 3. Precipitate may contain $Fe_2\ O_3$, $Al_2\ O_3$, $Cr_2\ O_3$ $Ur_2\ O_3$, $Al_2.\ O_3.\ PO_5$, BaO, SrO CaO, Mgo } PO_5 Examine by Table III.

To the filtrate, from the color of which a valuable inference may sometimes be drawn (CoO being indicated by a pink color, and NiO by a blue) $NH_4\ S$ is added in as slight excess as possible, and filtered. If the filtrate have a brown color indicative of dissolved NiS, it is evaporated till the excess of $NH_4\ S$ is expelled, acidified with dil. HCl and the precipitate thrown upon a filter and examined with that previously obtained.

Group 4. Precipitate may contain (Note *b*) CoS, NiS, MnS, ZnS Examine by Table IV.

To the filtrate add NH_3 and $NH_4\ O.\ CO_2$. Heat gently for some time and filter.

Group 5. Precipitate may contain BaO, SrO, CaO } CO_2 Examine by Table V.

Divide the filtrate into two portions, the one about 3 times the volume of the other.

To smaller portion add first a little $NH_4\ O.\ \bar{O}$. to be quite sure that all the BaO, $Sr\ O$ and CaO are precipitated, and then $2\ NaO.\ HO\ PO_5$. Agitate powerfully and set at rest for some time; white crystalline precipitate. $2\ MgO.\ NH_4O,\ PO_5$ Presence of MgO

Evaporate the other portion to dryness and heat until no more fumes are evolved Then if MgO be present treat the residue with HO and add BaO, HO till Alkaline reaction; Heat, filter, separate the excess of BaO by NH_3 and $NH_4\ O.CO_2$, filter, evaporate to dryness, ignite and test as follows for Alkalies. Re-dissolve in HO, filter and divide into two parts.

Test for NaO by exposing to blowpipe flame on platinum wire repeatedly dipped into the solution. Yellow flame, NaO.

Test for KO by adding HCl, $Pt.\ Cl_2$ and Alcohol, agitating and allowing to stand. Yellow crystalline precipitate KO, $Pt.\ Cl$. presence of KO. (See Table VI. for Ammonia.)

* SO_2 Sulphurous Acid.

a. When SO_2 is passed through the solution, the SO_3 formed on its Oxidation will convert any BaO, SrO, and PbO which may be present, into insoluble Sulphates—while it will *sometimes* reduce $CuCl$ into insoluble $Cu_2\ Cl$; if therefore a precipitate be obtained in this portion of the process, the supernatant fluid should be decanted, and the precipitate heated with dilute $HO.\ NO_5$, which will dissolve $Cu_2\ Cl$. and leave the insoluble Sulphates, which must be collected on a filter, washed, dried and treated according to the method for the analysis of substances insoluble in HO and Acids.

b. Small quantities of Manganese might not be obtained under this group, in consequence of its being precipitated under group 3, owing to the absorption of Oxygen from the air which converts the MnO in the Ammoniacal solution into insoluble MnO_2 which is precipitated together with $Fe_2\ O_3$, and the other members of group 3. It is therefore necessary, in case of any doubt as to the presence of Mn, to test a portion of this precipitate by fusion with $NaO.\ CO_2$ and $KO\ NO_5$.

TABLE I.

Analysis of the precipitate produced by HCl, which may contain Pb Cl, Ag Cl, Hg_2 Cl.

Boil with much water.

<table>
<tr><th>SOLUTION.</th><th colspan="2">RESIDUE.</th></tr>
<tr><td rowspan="3">Pb Cl.
Add dil, $HO. SO_3$ while hot.

White heavy precipitate.
PbO, SO_3
Presence of Lead.</td><td colspan="2">Ag Cl, Hg_2 Cl.
Wash by decantation and treat with
$N. H_3$.</td></tr>
<tr><td>SOLUTION.</td><td>BLACK RESIDUE.</td></tr>
<tr><td>Ag Cl
Add $HO. NO_5$ in excess; white precipitate Ag Cl. Presence of Silver.</td><td>Hg_2 O. Presence of Mercury.</td></tr>
</table>

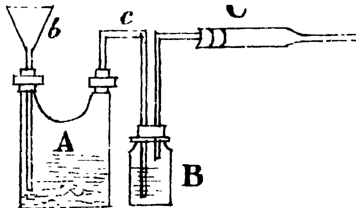
The Sulphide of Mercury, when boiled with concentrated $HO. NO_5$, is converted into a white Oxy Sulphide, which is perfectly insoluble in the Acid.

APPENDIX TO TABLE II.—(*See page* 195.)

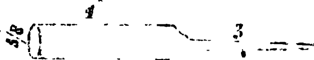
Process of Dr. Fresinius and Von Babo for testing the Sulphides of Arsenic

Requisites.

I.—An apparatus for evolving CO_2 Gas, (dry) consisting of, 1st—a generating bottle *A*, provided with a tube funnel *b*, for pouring in the Acid. In this bottle the CO_2 is evolved by the action of dilute *HCl* upon marble. A few fragments of marble are placed at the bottom of the generating bottle, the latter then half filled with *HO.* and concentrated *HCl* added by the tube *b*. 2nd, A wash bottle *B.*, three parts filled with oil of Vitriol ($HO. SO_3$) through which the CO_2 is conducted by the tube *c*, and where it is completely dried.



II.—A reduction tube *c*, made by heating a piece of *German* glass tube in the blowpipe flame, and drawing it out to a thin and open point. The length of the wide portion of the tube should be about 4 inches, that of the long point at least 3 inches, and as much longer as it may be drawn. The diameter of the wide portion of the tube should be about $\frac{3}{8}$ inch.

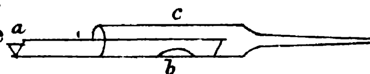


III.—An Agate Mortar in which the substances may be well ground and mixed.

IV.—A strip of rather stiff paper folded into a small gutter.

V.—Two spirit lamps.

The Sulphide of Arsenic, which must be perfectly dry, is mixed with about 12 times its weight of a mixture of about 1 part of *KO* and three parts of $NaO.\ CO_2$, which must both have been dried, and well pounded in an Agate Mortar. A portion of this mixture (about 20 grains) is placed upon the paper gutter (*a*) so as to lie in one spot (*b*.), the gutter is then introduced into the tube, and the latter turned, with the gutter half round upon its axis, so that the mixture may fall upon the spot (*b*.) of the tube; the gutter is then withdrawn, and the tube attached by means of a perforated cork to the tube delivering the dry CO_2.



A small quantity of *HCl* is then poured into the funnel tube, and the apparatus filled with CO_2 Gas which will require the lapse of one or two minutes.

If the evolution of CO_2 is, after this period, so violent that more than one bubble in a second passes through the wash bottle, water should be poured in through the funnel tube till the action is moderated to the required extent (one bubble in a second.)

The mixture at *b*. is now very gently heated, by waving a spirit-lamp beneath it, to expel all the accidental moisture, the drops which condense in the cool part of the tube are chased out by the spirit-lamp flame, and the tube then allowed to cool.

The shoulder of the tube at *a*. is heated to redness with the spirit-lamp flame, and the mixture is then gradually heated by the flame of another spirit-lamp, (the first lamp being still maintained in its former position) first at the extremity *b*.; the spirit-lamp being gradually advanced as the decomposition proceeds; to conclude the experiment, it is good to heat the spot *c*. strongly with the blowpipe flame. The result of the experiment should consist in the production of a lustrous mirror of *As* at *d*. which volatilizes when heated into a current of air, with the characteristic garlic odour, the latter being also generally perceptible throughout the course of the experiment.

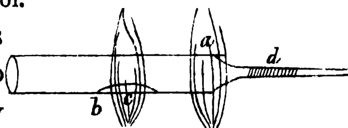


TABLE ..

Analysis of the precipitate produced by HS which may contain $Au\ S_3$, $Pt\ S_2$, $Hg\ S$, $Pb\ S$, $Bi\ S_3$, $Cu\ S$, Cd ~ $Sn\ S$, $Sn\ S_2$, $As\ S_3$, $Sb\ S_3$, $Sb\ S_5$. Heated for some time in a loosely corked flask with concd. NH_3 and a little S: (the S is only necessary when the precipitate has a dark color and might therefore contain Sn S) and filtered.

RESIDUE

May contain $Pt\ S_2$, $Pb\ S$, $Bi\ S_3$, $Cu\ S$, $Hg\ S$, $Au\ S_3$, $Cd\ S$.

Washed (till the washings give no precipitate with $Ag\ O.\ NO_5$.) and boiled with conc. $HO.\ NO_5$

RESIDUE

May contain $Pt\ S$ (in some cases) Au, $Hg\ S$ or the white (oxy-sulphide $PbO\ S\ O_3$.)

Dissolved in Nitro-hydrochloric Acid. The solution evaporated very nearly to dryness mixed with water in small quantity, $NH_4\ Cl$ added, and the solution set at rest for an hour.

- Yellow cryst. precipitate. $Pt\ Cl_2\ NH_4\ Cl$. Presence of *Pt*.

FILTRATE

May contain $Au\ Cl_3$, $Hg\ Cl$. Ammonia added to neutralize excess of acid and boiled for some time with $HO\ \bar{O}$ and evaporated to small bulk.

- Purple precipitate *Au*.
- FILTRATE. Boil with strips of bright copper wire. The strips will be silvered. They should be dried on blotting paper and heated in a tube (figure: tube, *a*) held in the flame of a spirit lamp somewhat obliquely (say at 45°) to allow of the passage of a feeble current of air. Globules of *Hg* appear at *A*.

FILTRATE

May contain PbO, $Bi\ O_3$, CuO, CdO, $Pt\ O_2$.

Evaporated nearly to dryness. (A white precipitate separating during this process, consists of $PbO\ SO_3$.) Diluted with water and a few drops of $HO\ SO_3$ added. The solution is allowed to stand a sh. . time.

- Precipitate $PbO.SO_3$. Presence of *Pb*.

FILTRATE

May contain $Pt\ O_2$, $Bi\ O_3$, CuO. CdO Evaporate to a small bulk, add $NH_4\ Cl$ and evaporate still further (add a little HO and if necessary HCl.)

- Precipitate $Pt\ Cl_2\ NH_4\ Cl$. Presence of *Pt*.

FILTRATE.

May contain $Bi\ O_3$, $Cu\ O$, CdO. Add NH_3 in excess.

- Precipitate $Bi\ O_3$. Dissolve in HCl evaporate to a small bulk and dilute with much water; milky turbidness. Presence of *Bi*.

FILTRATE.

$Cu\ O$, $Cd\ O$. Add *Kcy* till the blue color disappears; pass *HS*.

- Precipitate yellow $Cd\ S$; if not bright yellow, it will become so on redissolving in $HO\ NO_5$, adding HN_3, then *Kcy* and passing *HS*.
- FILTRATE. CuO. Add excess of $HO\ NO_5$ and boil; add a slight excess of NH_3 then acidify with $HO\ \bar{A}$ add $K_2\ Cfy$; red precipitate or color. Presence of *Cu*.

FILTRATE

May contain $Sb\ S_3$ or $_5$. $As\ S_3$ or $_5$, $Sn\ S_2$.

Add HCl in excess, and pass (to saturation) *HS*. The three sulphides are re-precipitated.

Agitate with $NH_4O.\ CO_2$ and gently heat (the *Sol* of $NH_4O.\ CO_2$ should have been saturated in the cold) and filter.

RESIDUE

May contain $Sb\ S_3$ or $_5$, $Sn\ S_2$. ash off the filter into beaker and boil with conc HCl, adding a few drops of $HO.\ NO_5$ to dissolve . whole. Add NH_3 till a permanent precipitate begins to appear, then $NH_4\ O.CO_2$ in excess. Boil for some minutes and filter.

- Precipitate $Sn\ O_2$ (and perh ps) $Sb\ O_5$. Dissolve off the filter in boiling conc HCl dilute in water and pass *HS*.
- Solution $Sb\ O_5$ add HCl in excess and pass *HS*. Orange precipitate $Sb\ S_5$. Presence of *Sb*.

(The dingy yellow color of the precipitate is a good indication of the presence of *Sn*.) Throw the precipitated sulphides upon a filter; wash till the washings give no precipitate with $AgO.\ NO_5$. Double up the filter, place it in a crucible, treat with concd. $HO\ NO_5$. Dry on a sandbath. Incinerate over a lamp, fuse the ashes with *Kcy* for some minutes and boil out the fused mass with water.

RESIDUE.

Metallic *Sb* and *Sn*. Washed by decantation, and boiled for some time with conc. HCl.

- Residue *Sb*.
- Solution $Sn\ Cl$. Divide into 2 parts.
  - To one part add $Hg\ Cl$; white precipitate $Hg_2\ Cl$
  - To the remainder add $Au\ Cl_3$, purple precipitate *Au*.

Solution $KO\ CyO$.

FILTRATE.

$As\ S_3$ or $_5$. Reprecipitate by HCl in excess and a little *HS*; collect the precipitate on a filter, dry at a low temperature on blotting paper, and divide into two parts.

- Dissolve one part in conc. $HO.NO_5$ and evaporate the solution to dryness. Re-dissolve the residue in water, add $Ag\ O.\ NO_5$ and a drop of Nh_3 Red precipitate $3AgO.AsO_5$ Presence of *As*.
- Test the remainder for *As* by the test of Fresinius and Babo described in another sheet.

Having used $HO,\ NO_5$ to dissolve the mineral, it may be evaporated to make a $H\ Cl$ solution, but then As Cl will go off, so it is better to dilute greatly the $HO,\ NO_5$, so that it may not oxidize the *H* of the *HS* about to be used as a precipitant.

The *HS* precipitant should be washed till the washings give no (or a mere trace of) precipitate with $AgO.\ NO_5$, before treatment with $HO,\ NO_5$, for otherwise Nt_3, $HO + H\ Cl$ will be formed and will dissolve the $Hg\ S$.

The sulphides of this group should when boiled, in NH_3 and *S* be placed in a tube with the two latter, the tube loosely corked and placed on a sandbath where it may boil very slowly for about an hour.

TABLE III.

Analysis of the precipitate of the third group, which may contain

$Ur_2 O_3$, $Fe_2 O_3$, $Al_2 O_3$, $Cr_2 O_3$, $Al_2 O_3 . PO_5$, $FE_2 O_3 . PO_5$, $\underbrace{Ba\ O,\ Sr\ O_2,\ Ca\ O,\ Mg\ O.}_{PO_5}$

Treat with Carbonate of Ammonia in the cold.

- **Filtrate.** Sesquioxide of Uranium. Evaporate nearly to dryness; yellow precipitate, Presence of Uranium. Confirm by adding Acetic Acid, and reprecipitating by Ferrocyanide of Potassium.
- Dissolve the residue of the Oxides off the filter with warm dilute HCL, add KO in excess and filter (in the cold to avoid precipitate of $Cr_2 O_3$.)
  - **Filtrate.** $Al_2 O_3$, $Al_2 O_3 . PO_5$, $Cr_2 O_3$. Boil for some minutes and filter.
    - **Filtrate.** $Al_2 O_3$, $Al_2 O_3 PO_5$. Add HOA in excess, stir well and filter.
      - **Filtrate.** $Al_2 O_3$. Add NH_3 White flocculent precipitate of $Al_2 O_3$.
      - Precipitate $Al_2 O_3 . PO_5$.
    - Precipitate $Cr_2 O_3$. Confirm with a bead of Borax.
  - Residue. $Fe_2 O_3$, $Fe_2 O_3 PO_5$, $Cr_2 O_3$ $\underbrace{BaO, SrO, CaO, MgO}_{PO_5}$ *Vide* notes to this Table. (Note I.) (Note II.)
    - Divide the above residue into two parts.
      - No. 1. Fused with Nitre and Carbonate of Soda, the fused mass dissolved in water, HOA added in excess and $PbO, \bar{A}$. Yellow precipitate of $PbO. Cr O_3$. Presence of Cr.
      - No. II. Dissolved off the filter in warm dilute HCl, $HO\bar{T}$ and NH_3 added.
        - **Filtrate.** $Fe_2 O_3$, $Fe_2 O_3 PO_5$, $Cr_2 O_3$ Divide into two parts.
          - To one part add $HO\bar{A}$ and $K_2 Cfy$ Blue precipitate; Presence of Fe.
          - To the other part add $Am\ Cl$, AmO, and $MgO. SO_3$ Crystalline precipitate. Presence of PO_5.
        - Precipitate. Phosphates of BaO, SrO, CaO, MgO.
          - Dissolve in HCl, add $KO. \bar{A}$ and $Fe_2 Cl_3$, until a distinct pink color is produced, boil for some minutes and filter while hot.
            - **Filtrate.** $Ba\ Cl.$ $Sr\ Cl.$ $Ca\ Cl.$ $Mg\ Cl.$ Test as usual, *Vide* Note III.)
            - Precipitate. $Fe_2 O_3 \bar{A}$, $Fe_2 O_3 PO_5$ dissolve in HCl add NH_3 and $NH_4 S$. Filter.
              - Precipitate. $Fe\ S$.
              - **Filtrate.** $2 NH_4, O. HO. PO_5$, Add NH_3, $NH_4\ Cl$ and $MgO. OS_3$ White crystalline precipitate $2\ MgO. NH_4 O. PO_5$. Presence of PO_5 Note IV.

I.—If no or very little $Fe_2 O_3$ be present, all the $Cr_2 O_3$ will be found in the KO solution, but if there be much $Fe_2 O_3$, it will carry down the $Cr_2 O_3$, either in part or entirely.

II.—Traces of $Ca\ F$ sometimes come down in this Table; It would behave throughout like the Phosphates in such a case, all that would be required, would be to prove distinctly the absence of PO_5 altogether disregarding every thing else.

III.—If the addition of $NH_4\ Cl$ and NH_3 to this solution, containing $Ba\ Cl$, $Sr\ Cl$, $Ca\ Cl$, and $Mg\ Cl$, should produce any precipitate, it should be regarded as $Fe_2 O_3$, and filtered off previously to testing for the Alkaline earths.

IV.—It is better to evaporate the solution filtered from the $Fe\ S$ till it no longer smells of $NH_4 S$ before testing it for PO_5.

The residue obtained on evaporating the HS filtrate, is boiled with Conc $HO\ NO_5$, to convert any Oxalates of the Alkaline earths, which may be present into Nitrates, which will not be precipitated by $NH_4\ Cl$ and NH_3.

TABLE IV. (see Note C.)

Precipitate produced by Protosulphide of Ammonium, (white, flesh colored, black and intermidiate shades.)

Protosulphide of Zinc, Protosulphide of Manganese, Protosulphide of Nickel, Protosulphide of Cobalt. Wash, dissolve in Nitric Acid and add excess of Potassa.

FILTRATE

Protoxide of Zinc in Alkaline solution. Add Hydrosulphuric Acid; White precipitate of Protosulphide of Zinc. Presence of Zinc Confirmatory Test, Heat with Cobalt solution on Charcoal; Green Mass of Protoxide of Zinc and Protoxide of Cobalt. See Note A.

PRECIPITATE

Protoxide of Manganese, Protoxide of Nickel, Protoxide of Cobalt; Wash; Dissolve in Hydrochloric Acid; add Carbonate of Ammonia.

PRECIPITATE.

(White) Carbonate of Protoxide of Manganese. Presence of Manganese; Confirmatory Test, Fuse with Nitre and Carbonate of Soda on Platinum foil. Green Mass of Manganate of Soda.

FILTRATE (see Note B.)

Carbonate of Protoxide of Nickel, Carbonate of Protoxide of Cobalt in Ammoniacal solution. Add Protocyanide of Potassium until the solution is decolorized, and a slight excess of Hydrochloric Acid.

PRECIPITATE.

Cobalticyanide of Nickel, Protocyanide of Nickel. Collect on a filter and boil with Potassa.

PRECIPITATE.

(Yellowish Green) Protoxide of Nickel. Presence of Nickel.

FILTRATE.

Cobalticyanide of Potassium. Mix both filtrates, evaporate to dryness, ignite the residue, wash it with *water* and heat it with Borax, before the blowpipe flame or Platinum wire. Violet blue bead. Presence of Cobalt.

FILTRATE.

Cobalticyanide of Potassium.

NOTE A. The precipitate which should be white Sulphide of Zinc, has sometimes a black color, due to impurities in the Potassa ($Fe\ S$, $Pb\ S$,) In order to ascertain the presence of Zn, this precipitate should be dissolved in $HO.\ NO_5 + H\ Cl$: $NH_4\ Cl$, and NH_3 added, to throw down the $Fe_2\ O_3$ or $Pb\ O$, and HS passed through the Ammoniacal filtrate, when white $Zn\ S$ will be precipitated.

NOTE B. The Ammoniacal solution which contains $Ni\ O,\ CO_2$ and $Co\ O,\ CO_2$ should be mixed with HCl in slight excess, evaporated to a small bulk, $K\ Cy$ added in excess, boiled, HCl in excess then added, the solution evaporated till it smells no more of $H\ Cy$ and excess of $K\ O$ added; the mixture boiled and filtered.

PRECIPITATE.	FILTRATE.
$Ni\ O$. Washed and examined before the blowpipe.	$K_3 Co_2 Cy_6$ Evaporated to dryness, ignited and tested before the Blowpipe for Co after extracting the greater part of the $KO\ Cl$ by HO.

NOTE C. If the filtrate from the $NH_4\ S$ precipitate have a brown color it should be evaporated nearly to dryness, to precipitate the $Ni\ S$, a few drops of $H\ Cl$ added to Acid re-action (in order to dissolve any earthy Carbonates), filtered, and the filtrate examined, as usual, the $Ni\ S$ being examined with the $NH_4\ S$ precipitate.

TABLE V.

Precipitate produced by Carbonate of Ammonia, in the presence of Chloride of Ammonium. (See Note 1.)

(White)
Carbonate of Baryta, Carbonate of Strontia, Carbonate of Lime,
Dissolve in Acetic Acid, (Solution *A.*)
Dilute a portion with water, add Chromate of Potassa, and heat to ebullition.

PRECIPITATE.	FILTRATE.	
(Yellow) Chromate of Baryta; Presence of Barium. Confirmatory test with *solution A;* Add *Hydro-fluosilicic* Acid, white Crystalline precipitate of Silico-fluoride of Barium.	Acetate of Strontia, Acetate of Lime and Chromate of Potassa. (See Note 2.) Add Carbonate of Ammonia, wash the precipitated Carbonates of Strontia and Lime, until the yellow color has disappeared, and dissolve in Hydrochloric Acid. Evaporate to dryness, re-dissolve in Water and divide into two portions.	
	1.	2.
	Add Sulphate of Lime and allow to stand for some time. A white precipitate of Sulphate of Strontia; Presence of Strontium. Confirmatory test with solution *A.* Evaporate to dryness, add a few drops of Hydrochloric Acid and Alcohol and ignite the mixture. (See Note 3.) The red flame of the Alcohol is characteristic only, if the absence of Lime has been proved.	Add Sulphate of Potassa, (see Note 4,) heat gently, allow to stand for some time and filter off from the white precipitate of Sulphate of Strontia. To the filtrate add Oxalic Acid. A white precipitate of Oxalate of Lime; presence of Calcium.

Note 1. In the precipitation of this group by $NH_4\ O,\ CO_2$ the following conditions must be carefully attended to :—

1.—The presence of caustic Ammonia which much promotes the precipitation of the Carbonates.
2.—The presence of $NH_4\ Cl$, to prevent the precipitation of MgO.
3.—The solution must be heated nearly to ebullition to convert any Bicarbonates of the Alkaline earths, (which are soluble) into the insoluble Carbonates.

The precipitate of $BaO.\ CO_2$, $Sr\ O.\ CO_2$ and $CaO.\ CO_2$ is dissolved in $HO.\ \overline{A}$, and the solution divided into two parts.

The larger quantity of solution is treated as in the Table	A small portion is saved for the confirmation of the presence of SrO and BaO, as stated in the Tables.

Note 2. In the precipitation of $Sr\ O,\ CO_2$ and $Ca\ O,\ CO_2$ from the filtrate containing the Acetates of $Sr\ O$, and $Ca\ O$, and $KO,\ CrO_3$, the first and third of the above mentioned conditions must be fulfilled.

Note 3. In the confirmation for $Sr\ O$ by means of the Alcohol flame, it is better to burn the suspected $Sr\ O$ solution side by side with an Alcoholic solution of $Ca\ Cl$, in order that the CRIMSON of the former may be brought into contrast with the *yellow red* of the latter.

Note 4. The solution containing $Sr\ O$ and CaO from which the former is to be separated by $KO,\ SO_3$, should be as concentrated as possible.

TABLE VI.

(Magnesia,) Potassa, Soda, (Ammonia.)

$N\ H_3$ should always be tested for in the preliminary examination by mixing the substance with dry $Ca\ O,\ HO$, moistening with HO and heating, when vapour of NH_3 will be evolved, and may be tested by reddened Litmus Paper and with Hydrochloric Acid.

ANALYSIS OF A COPPER ORE.

PRELIMINARY EXAMINATION.

Fused a portion before the blowpipe (reducing flame) with $NaO.CO_2$ and KCy upon Charcoal.

Obtained a fine malleable bead of *Cu*, without incrustation or garlic odor.

Powdered about 30 grains of the mineral, and boiled with concentrated HCl for some minutes. ($HO.\ NO_5$ would have been used, but that the appearance of the mineral led to its being mistaken for a piece of Iron stone, until the preliminary examination above detailed had shown the contrary). A dark greenish solution was obtained, which, when diluted, gave a copious white precipitate.

A portion of this precipitate was separated and examined as follows:

1. A small portion was treated with dilute $HO.\ NO_5$. It entirely dissolved.
2. Another portion was treated with concentrated HCl. It dissolved with a dark color and was re-precipitated by water.
3. A third portion was treated with NH_3. It entirely dissolved.

These experiments having sufficiently proved that the white precipitate in question was $Cu_2\ Cl$ (Subchloride of Copper), the whole of this precipitate, together with the HCl solvent in which it was suspended, was mixed with a little $HO.\ NO_5$ and the whole heated upon a sand-bath till the solution gave no longer a precipitate on dilution with HO.

The solution was then evaporated to dryness on a sand-bath, and the residue perfectly dried to render the $Si\ O_2$ insoluble. The dry mass was thoroughly moistened with concentrated HCl, a moderate quantity of water added, heat applied to effect complete solution, the residue of $Si\ O_2$ filtered off, and the solution saturated with $H\ S$.

ANALYSIS OF COPPER ORE,—(*Continued.*)

<table>
<tr>
<td colspan="4">PRECIPITATE.
Washed and gently heated with conc. NH_3 and a little S. for some time.</td>
<td colspan="6">FILTRATE.
Evaporated till the excess of $H\ S$. was expelled; mixed with a little concentrated $HO. NO_5$ to oxidize any $Fe\ O$ evaporated to a small bulk; $NH_4\ Cl$ and excess of NH_3 added, and filtered.</td>
</tr>
<tr>
<td colspan="2">RESIDUE.
Washed and boiled with concentrated $HO. NO_5$.</td>
<td colspan="2">FILTRATE.
Had a pale blue color, showing that it contained Cu. Passed a few bubbles of $H\ S$ till the Solution became colorless and filtered.</td>
<td colspan="3">RED-BROWN PRECIPITATE.
Dissolved in HCl, added KO in excess, boiled and filtered.</td>
<td colspan="3">FILTRATE.
Added $NH_4\ S$. No precipitate.
Evaporated to a small bulk, acidulated with HCl, filtered from separated S, added NH_3 and $NH_4O.\ CO_2$ and gently heated.</td>
</tr>
<tr>
<td rowspan="2">RESIDUE.
Dissolved in $H\ Cl + HO. NO_5$ added NH_3 in slight excess, then acidified with HCl and boiled with slips of Cu; finding the latter were covered with a dark film, they were dried on blotting paper and heated in a tube. No sublimate was obtained.
No HgO.</td>
<td rowspan="2">FILTRATE.
Evaporated to expel excess of Acid, and added $HO. SO_3$. No precipitate.
No Pb.
Added excess of NH_3. No precipitate.
NO Bi.
Deep blue color, presence of Cu, added KCy till the solution was colorless and passed HS.
No precipitate.
No Cd.</td>
<td rowspan="2">Precipitate.
Cu S.</td>
<td rowspan="2">FILTRATE.
Added HCl and passed $H\ S$. No precipitate except Sulphur.
No Sb, Sn, or As.</td>
<td colspan="2">PRECIPITATE.
Dissolved in HCl. 2 $HO. \bar{T}$ and excess of NH_3 added.</td>
<td rowspan="2">FILTRATE.
Added $HO. \bar{A}$ in excess
No precipitate.
No $Al_2O_3PO_5$
Added NH_3 in excess. White flocculent precipitate.
Presence of Al_2O_3.</td>
<td rowspan="2">PRECIPITATE.
Very slight trace of $CaO.\ CO_2$.</td>
<td colspan="2">FILTRATE.
Divided into 2 parts.</td>
</tr>
<tr>
<td>No precipitate.
No Phosphates.</td>
<td>Solution had no greenish color.
No Cr.
Added to it $HO\ \bar{A}$ in excess and $K_2\ Cfy_3$.
Blue precipitate.
Presence of Fe.</td>
<td>To one small part added 2 $NaO\ HO\ PO_5$ agitated and allowed to stand. Considerable cryst, precipitate.
Presence of MgO.</td>
<td>The remainder was evaporated to dryness and the residue ignited.
No residues.
No Alkalis.</td>
</tr>
</table>

PART III.

PRACTICAL APPLICATION.

SECTION I.

AGRICULTURE.

1.—It would not be difficult to write a volume on the application of the matter contained in the foregoing pages to the purposes of all classes who take an interest, not only in the advancement and prosperity of this country, but in their own personal comfort and advantage.

2.—In India there are not to be found everywhere, as in England, men of science and education, who have devoted their lives to the close and practical study of some one of the sciences, and who may be applied to without more difficulty and delay than is involved in the transit of a letter by penny post, or perhaps a personal visit, accomplished by express train in a few hours. Men who are as competent as they are willing to unravel the knotty questions of science, and who have the advantage also of being in close communication with the equally scientific of all the countries of Europe. It is not so in India. We must do our own work here, or else we must undergo the delay of a tedious reference, with the disadvantage, perhaps, of defective information supplied on the one side, and want of interest in the subject on the other; defects inseparable almost from the nature of circumstances.

3.—Great part of the most intricate and difficult of the matters, I refer to, must, I fear, inevitably be left to the more accomplished and competent in England. This would indeed be the case in that country itself. But, on the other hand, very much of a preparatory and most useful kind may be effected by ourselves, and if this can be so, where will be the advantage of sending to England our soils and stones, our waters, or manures, or metals to have their simple constitution defined, when it may be done sufficiently to answer most purposes by individuals on the spot.

4.—To endeavour to promote this personal examination by the discoverer or observer himself, has been the object of the foregoing pages,

and I would hope that the advantages to be derived to Agriculture, to Engineering, to sanitary and scientific objects generally, are so palpable to every one, that it will not be necessary for me, in this place, to say much in order to explain them to the reader.

5.—For the reasons given in the Preface, however, I must leave it more than I could have wished, or than I had at first any intention of doing, to the student himself to deduce the applications of what he may have learned in the foregoing pages to practical purposes.

6.—This will be no difficult task, nor will he be slow to discover, not only that his chemical knowledge applies to almost everything that comes before him, from the kitchen to the laboratory, but also how intimately the future welfare of this country is connected with the progress that may be made in Geological Chemistry. The perfection and increase of its agricultural produce; the discovery of metals, coal, and all natural products, may be incalculably assisted, if the sportsman in ranging the country for game, the military man visiting his out-posts, or the Civilian inspecting his District, can add to their other acquirements a little, even a very little, knowledge of the subject of these pages.

7.—In addition to this, he will most surely find, as I and others similarly situated with himself can tell him from experience we have found, that science is its own reward, and that a constant flow of the purest pleasure rewards those who follow her paths.

8.—I propose first to touch on some of the subjects included under the heads Agricultural and Medical, as these are in a great measure linked together.

9.—Within the last 12 or 14 years, the knowledge and science of the Chemist have been constantly called in to the aid of the farmer and agriculturist, and much has been discovered and applied practically, in that department. The views of Liebig, the great authority on this subject, are distinct and clear; let us glance over them in their main features.

10.—It was supposed formerly that the best way to enrich a soil, and obtain from it the finest crops, was to diffuse through it a quantity of mixed vegetable and animal matter in a state of decomposition; by which means a rich mould, containing a substance called "Humus," supposed to be the nutritive principle of good soil, was generated, which was absorbed by the roots, and highly promoted the growth of plants.

11.—A variety of circumstances, however, have been found which are not in accordance with this view. Liebig has shown that, under the most favorable circumstances, the quantity of humic acid which could be absorbed, is not sufficient to produce the amount of woody

fibre found in trees. Common instances, familiar to every one, show that some plants and flowers flourish without any humus or soil whatever, as suspended hyacinths, mustard seed sown on a piece of flannel, and marine plants or sea-weeds, which, growing to a height of more than 300 feet, and nourishing multitudes of animals on their branches, have yet but a root the size of a man's fist, fastened on a naked rock. It was hence deduced that it must be by Carbonic Acid, or by some Gas evolved in the earth, or derived from the atmosphere, that they are nourished.

12.—Humus is proved to be *not* soluble, as was supposed. The experiments of Chemists show that "both the cold of winter and the heat of summer are destructive of the solubility of humic acid, and at the same time of its capability of being assimilated by plants. So that if it is absorbed by plants, it must be in some altered form." "The correctness of these observations is easily demonstrated by treating a portion of good mould with cold water. The fluid remains colorless, and is found to have dissolved less than 100,000th part of its weight of organic matter, and to contain merely the salts which are present in rain water."*

13.—Again, a soil does not become any poorer in Humus from the abstracting operation of plants growing in it, as shown by its assuming a paler tint or more sandy or aluminous texture. On the contrary, it becomes darker. Some portion of the soil is, no doubt, elaborated and absorbed into the plant, while another portion, detrimental to itself, appears to be rejected, (Coal of Humus, Liebig calls it,) but which may be again nutritious under other forms or to other species. Hence the advantage of rotation of crops and of fallow years.

14.—As regards the air, Mr. Ward's experiments on plants in enclosed cases have shown that *fresh* air is not absolutely necessary to their healthy existence. They appear, therefore, to have the power of renewing their atmosphere in accordance with that theory which describes them as exhaling Oxygen, when under the influence of light and heat (and electricity?) but ceasing to do so at night.

15.—This alternating action of plants, and the consequent neutral and beneficial relation between them and animals, has been very beautifully shown by actual experiment in the aquariums, or globes containing fishes, snails and weeds, by Mr. Warrington, Gosse, &c. Either of these remaining singly in the water for a considerable period, languished and died, but when the three were introduced together, the

* Sir J. Paxton, Magazine of Botany.

plants, absorbing Carbonic Acid from the excrementitious matter of the fishes, flourished, while at the same time secreting the Carbon for their own use, and giving out the Oxygen, the fish were by the latter maintained for any length of time in health and vigor.

16.—The air diffused in sea water contains 33 per cent. Oxygen, the atmospheric air only 21. The fish consumes the Oxygen of the air thus diffused in the water, feeds on the insects and, by its excrement, also supplies manure for the plants. The plants give out Oxygen by their vital processes, which restores the water to its healthful state; and they also assist in preserving the purity of the water, by absorbing the decomposing animal matter or manure of the fish and snail. The snails feed on the decaying portions of the weeds, which would otherwise prove hurtful to the fish, and their eggs serve as nourishment to the latter.

17.—When the fishes and plants only were introduced without the snails, it was found that the accumulation of decaying matter from the plants, produced a slime which proved injurious to the fish.

18.—The Humus theory then is now abandoned, and has given way to a more enlarged and exact view of the subject.

The chief object of all agriculture is to obtain crops of produce which, by their abundance and nutritive qualities, may prove rapidly, as well as permanently beneficial, both to man and to the domestic animals by whom he is surrounded. It has been found from the earliest times, that whereas a new and virgin soil will grow fine crops during the first few years of its cultivation, it becomes in a short time impoverished, and incapable of continuing to produce crops of equal quality of the same kind.

19.—It has also been found that, although this soil will not continue to grow good crops of the same kind, it may and will produce equally fine crops with other kind of some different kind of grain, or that, if assisted by the admixture of some foreign ingredient or manure, or even allowed to lie fallow, it will recover its full fertility.

20.—From these considerations arise three questions of very great importance, which must be referred to the analytical chemist to answer:—

These are, 1*st.*—What are the constituent parts of soils, and what in particular those parts, by the abstraction of which in the successive growth of crops, the soil becomes impoverished?

2*ndly.*—What is the ultimate constitution of grain or other agricultural produce, and what are the substances necessary to be adminis-

tered to it during its growth, so as to obtain its full and most perfect development, both as to quantity and quality?

3rdly.—What are the parts of the human and animal economy which require constant sustenance and replenishment? On what does their maintenance in full development, and their healthy condition depend?—and what are the matters, by the absorption of which into the frame, the system is preserved in its most robust and perfect action?

21.—To reply to these questions, it is necessary to make *analyses of various soils,* so as to comprehend their usual natural ingredients, organic and inorganic, at different periods, and those that should be added to them as manures to make them fertile.

2ndly.—To analyse *cereal produce,* and other matters most usually employed for the purpose of nourishment of man and animals.

3rdly.—To *analyse the different parts of the human frame* on which health and strength are supposed to depend, as the blood, bones, &c.

We should then, after such Analyses taken in sufficient number, be prepared to understand what nutritive qualities it is most desirable and to our advantage to find in our different varieties of agricultural produce, and what are the substances or manures by the employment of which we shall be most likely to obtain these, and maintain our lands in such a state, that they may be adapted most economically and permanently to such produce as it may be found most beneficial to grow upon them.

22.—It is evident that the air, as well as the moistened soil, plays an important part in the nourishment of plants. In short, their existence and development depend as much upon the absorptive action of their leaf surfaces as of their roots. The latter separate from the soil the mineral ingredients which it may contain in a fit state of solution, and which are necessary for the formation of the leaves and vegetable tissues, by the agency of which the Carbonic Acid and Ammonia, also necessary to their existence, are absorbed from the air.

23.—Basalt, Graywacké, Porphyry, Sandstone, Limestone, contain certain elements indispensable to the growth of plants, and the presence of which renders the soil fertile. The fertilizing property of the ashes of burnt grass and jungle, arising from their ashes containing the same ingredients, is adverted to by Major Colebrooke in his report on the Ganges river, as being well known by the natives, who purposely have recourse to conflagration at certain seasons, for the improvement of the new lands situated on the islands, thrown up from time to time by the river in its bed.

24.—It is from the constituents of the ashes of plants, ascertained by Analysis, that we learn what mineral ingredients are essential to each particular species, and it is by affording these to an impoverished soil, or to one wanting in them altogether, that we are able to promote the healthy and rapid growth of any plant that may be desired.

25.—Thus the art of agriculture depends on the *restitution of a disturbed equilibrium*, and it should be our duty to return to the soil, in the form of manures, what is abstracted from it by plants or crops during their growth, and these matters are to be ascertained by careful Analysis of the ashes of the plants themselves.

26.—The chief mineral ingredients thus required in manures, are Silica, the Alkalies, and the alkaline and earthy Phosphates.

Silica in its soluble form, combined with Potash, *i. e.*, Silicate of Potash, is a plentiful ingredient of many of the hardest rocks, and where it exists in abundance, wheat crops, or crops of the Cerealia, might be grown probably year after year with success, as in some part of Hungary and Italy; but where it is not so abundant, "fallow" years are requisite, in order that while potatoes, clover, turnips, &c., which do not require so much Silica, are growing, the soil may have time to recover its fertility, by receiving from the gradually disintegrating rocks the requisite amount of the supporting ingredient, Silica.

27.—Quick-lime assists this process of bringing the Silica into solution. Liebig says Felspar, even when reduced to the finest powder, requires for its solution to be treated with an acid for weeks or months; but if we first mix it with Quick-lime and expose the mixture to a moderately strong heat, the Lime enters into chemical combination with certain elements of the Felspar, and its Alkali (Potash) is set free, and now the acid, even without heat, dissolves not only the Lime, but also so much of the Silica of the Felspar, as to form a transparent jelly; a similar effect is exerted by Lime on the alkaline argillaceous Silicates.

28.—Common Potter's Clay or Pipe-clay diffused through water and added to Milk of Lime, thickens immediately upon mixing; and if the mixture be kept for some months, and then treated with acid, the Clay becomes gelatinous, which would not occur without the admixture with the Lime. The Lime, in combining with the elements of the Clay, renders it soluble, and what is more remarkable, liberates the greater part of its Alkalis. Hence arises a part of the benefit derived from Quick-lime as a manure.

29.—A no less favorable influence than that of Lime is exercised upon the soil of peaty land by the mere act of burning it. Many of

the clay Silicates in their natural state, are not acted on by acids, but they become perfectly soluble if heated to redness before the application of the acid. This property belongs to Potter's Clay, Pipe-clay, Loam, and many different modifications of Clay in soils. In their natural state, they may be boiled in concentrated Sulphuric Acid without sensible change; but if gently calcined, as is done with the Pipe-clay in many Alum manufactories, they dissolve in the acid with the greatest facility, the contained Silica being separated like a jelly in a soluble state.

30.—Both rain water and sea water contain Carbonic Acid, and this, in course of time, proves a powerful agent in disintegrating the hardest rocks, and reducing them to the state of soil, containing the primitive ingredients in a highly comminuted or even soluble state, in consequence of its affinity for the Alkalis, Potash, Soda and Lime especially, which exist in these rocks. Even Granite may thus be seen to peel off in layers, particularly if it contain a large quantity of these Alkalis, and thus are frequently worn or worked out, the granite boulders and caves which are found in all parts of the world.

31.—The Alkalis, Potash and Soda, as also the Earths, Lime and Magnesia, are thus derived then in great part by the agency of Carbonic Acid from the various rocks and substances containing them, and of this agent a plentiful supply always exists naturally in the air, from the exhalation of animals, and from the decay of organic matters; humus and other substances supplying the Carbon, by the combination of which with the Oxygen of the air, Carbonic Acid (or CO_2) is produced.

32.—Of all the elements, however, ministering to the nourishment of plants, Liebig says, he regards Phosphate of Lime, or rather the Phosphates generally, as the most important. These are derived chiefly from animal remains, and the principal sources at present are bones, guano, animal excrements, and some rocks, such as the Limestones, which, holding embedded organic remains or coprolites, or such material, afford by their disintegration the Phosphoric Acid which enters into their constitution.

33.—Chlorine (and Soda also) is derived from common salt, ($NaO.\ Cl$) and Sulphur from Gypsum or Sulphate of Lime, both common ingredients in soils.

34.—Iron, whose universally diffused presence, not only in the earth but in the air, and in the blood of the human frame, is somewhat mysterious, is every where an ingredient of the soil, and the influence of its red colored Peroxide (Fe_2O_3), being its simple combination with the

Oxygen of the atmosphere, may be universally recognized in the tints of the soil, and the hues of the weather-stained surfaces of rocks.

35.—When to the above we add Manganese, which is also commonly found, we have enumerated the chief substances which Analysis discovers in the soil of the earth, and which experience shows to be absolutely necessary in various proportions to the growth of vegetation.

This may be seen from the following few Analyses (Sprengel's) of some soils:

INGREDIENTS.	SOILS.		
	1	2	3
Silica,	95·698	90·221	95·660
Alumina,	·504	2·106	1·586
Peroxide and Protoxide of Iron,	2·496	3·951	1·616
Peroxide of Manganese,	a trace	·960	·240
Lime,	·038	·539	·083
Magnesia,	·147	·730	·080
Potash and Soda,	·090	·076	·250
Phosphoric Acid with Iron,	·164	·367	·039
Sulphuric Acid (Gypsum,)	·007	a trace	·003
Chlorine in Common Salt,	·010	·100	a trace
Humus,	·846	·900	·440
	100·000	99.950	99·997

36.—Not only is the chemical constitution of a soil a matter of absolute importance, but so, in no less degree, is its mechanical condition.

A too clayey soil, by its compactness, will forbid the access of air, and will retain moisture too much. It will be a "cold" soil. Hence the benefit of sand, ashes or such material, to render it more permeable to air, and to the spreading roots of growing plants—and to prevent the retention and evaporation on the surface of water generating cold. If the air be excluded, Oxygen cannot be obtained, nor Carbonic Acid generated from the Carbon of the decaying manure, and the advantage of this agent has been previously explained. The ashes of Coal and Lignite are useful for this purpose. The most suitable may be readily known by their property of forming a gelatinous mass when treated with acids, or by becoming, when mixed with Cream of Lime as a mineral solvent, like hydraulic cement, solid and hard as stone.

37.—On the other hand, a too open or sandy soil passes rapidly through it all falling moisture, and owing to the too free exposure it affords; and consequent rapid decomposition, loses much of the benefit which, had it been more compact, would have been derived from the

manure bestowed upon it. Hence it is benefitted by an admixture of clay or marl.

38.—The color of a soil is of importance in its way, especially while the seed is yet in the ground, because it absorbs heat or becomes warm more rapidly than a light colored earth. A black mould, exposed to the sun, gains more than four times as much heat, as a white chalk soil will do in the same time. Dark soils also radiate their heat more rapidly, and as dew is owing to the condensation of radiated heat, such soils condense and absorb more moisture.

39.—The power of absorption and condensation in a soil, is dependant both on its quality and on its degree of compactness or porosity. Liebig says—"all porous bodies, rocks, stones, the clods of the fields, imbibe air, and therefore Oxygen; the smallest solid molecule is thus surrounded by its own atmosphere of condensed Oxygen; and if in their vicinity other bodies exist, which have an affinity for Oxygen, a combination is effected. When, for instance, Carbon and Hydrogen are thus present, they are converted into nourishment for vegetables, into Carbonic Acid and Water. The development of heat, when air or watery vapor is absorbed, or when the earth is moistened by rain, is acknowledged to be the consequence of this condensation by the action of surfaces." The *extent* of condensing *surface* in a porous body, be it remembered, is very large in proportion to its size; a cubic inch of beech wood charcoal being computed to have at least 100 square feet of surface.

40.—We observe, therefore, that both the chemical and mechanical state of the soil must be attended to, in order to obtain good results. Phosphate of Lime and Magnesia are always found in the seeds of plants. A seed sown in a soil consisting simply of Silica, and having all other requisites for its growth supplied to it, except the mineral ingredients, such as the above, might germinate and produce the first organs of growth, but would cease to increase as soon as the supply, contained for its use in the seed itself, was exhausted. A feeble stalk and even a flower may be produced in some instances, but no seed; as those materials are wanting, without which neither the stalk nor leaves can be fully developed, nor the seed produced.

41.—Hence without doubt the reason why we so often see that vegetables or flowers, which grow well in one part of the country, refuse to flower or give seed, or perhaps to grow at all, in others. Thus it has been with the Celery which, growing luxuriantly in Sinde, fails altogether, in spite of every care, in other places; with the

Strawberry, which, giving an ample and easy crop at Meerut, returns but little reward to the cultivator across the river at Delhi; and with the Sweet Pea, which grows, but declines to flower or seed, in many parts of Bengal. Many other instances, such as the Cocoanut growing only within the influence of the sea breeze, &c., will doubtless occur to the reader.

42.—By analyzing the ashes of such plants, we should find the mineral ingredients of which they consist, and by analyzing our soils, we should find whether they afforded the ingredients in question, or in what they were wanting. The ashes of Vines, Peas, and Clover, contain a large quantity of Lime, and accordingly they do not flourish in soils destitute of Lime; but by applying Lime to such soils, they are rendered capable of supporting these plants.

43.—That the seeds and straw of all plants contain these mineral ingredients of the soil, will be seen by the following Analysis of the ashes of several of them:

	WHEAT.		BARLEY.		OATS.		RYE.		PEAS.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
Potash, ...	·225	·020	·278	·180	·150	·870	} ·532	·082	·810	·235
Soda, ...	·240	·029	·290	·048	·132	·002		·011	·739	......
Lime, ...	·096	·240	·160	·554	·086	·152	·122	·178	·058	2·730
Magnesia, ...	·690	·0[illegible]	·180	·076	·067	·022	·044	·012	·136	·342
Alumina, ...	·026	·090	·025	·146	·014	·006	·024	} ·025	·020	·060
Iron,...	......	trace.	trace.	·014	·040	·002	·042		·010	·020
Manganese, ...	......	ditto,	ditto,	·020	......	.002	·034	......	......	·007
Silica, ...	·400	2·870	1·112	3·856	1·976	4·588	·164	2 297	·410	·996
Sulphuric Acid,	·050	·037	·059	·118	·035	·079	·023	·170	·053	·337
Phosphoric Acid	·040	·170	·210	·160	·070	·012	·046	·051	·190	·240
Chlorine,... ...	·010	·030	·019	·070	·010	·005	·009	·017	·038	·004
In 100 parts Ash,... ...	1·777	3·518	2·333	5·242	2·580	5·740	1·040	2·793	2·464	4·971

44.—The soluble saline matters in soils may sometimes be in excess, and they are then sometimes seen, when much rain and heat alternate, to effloresce on the surfaces of leaves, as of carrots, pumpkins, or peas; and on the other hand they may be defective, when it will be found that the seeds, young leaves and buds are appropriating all that there is, while the older leaves, deprived of their share, wither and fall off.

Some Salts in excess are hurtful to plants, as the Sulphate and Protoxide of Iron.

45.—The mineral ingredients of the soil, derived in the first place from the decomposition of rocks, then absorbed by plants, and con-

sumed by animals in their food, are again returned to it in the excreta of these animals, that is in manures, to be again assimulated, and again perform the circle of operations prescribed for them by nature. In the excrement of the dog, fed on bones and flesh, we have almost pure white Phosphate of Lime, with scarcely one per cent. of foreign organic matter. In other animal manures, we obtain from the solid portions the insoluble Salts, as the Phosphates of Lime and Magnesia, and in the liquid portion Ammonia (NH_3) the source of Nitrogen, and also the Alkalis, Soda and Potash, and the soluble Phosphates and Sulphates.

46.—It is a most curious fact, Liebig says, that if we incinerate *grain* or its flour, peas, beans, and lentils, we obtain ashes which are distinguished from the ashes of all *other* parts of vegetables by the absence of alkaline *Carbonates.* They contain the alkaline *Phosphates*, the very same Salts which are contained in blood, and indispensable to its formation. Hence we are led to the conclusion that the presence and co-operation of the Phosphates is absolutely necessary to the formation of the cereal food of man and animals. A field in which Phosphate of Lime or the alkaline Phosphates, form no part of the soil, is totally incapable of producing grain, peas, or beans, says Liebig.

47.—Moreover, "the solid and liquid excreta of an animal have the highest value, as manure for those plants on which the animal has been fed. Thus the excrements of pigs which we have fed with peas and potatoes, are principally suited for manuring crops of potatoes and peas. In feeding a cow upon hay and turnips we obtain a manure containing the inorganic elements of grasses and turnips, and which is therefore preferable for manuring turnips. The excrement of pigeons contains the mineral elements of grain; that of rabbits, the elements of herbs and kitchen vegetables. The fluid and solid excrements of man, however, contain the mineral elements of grain and seeds in the greatest quantity.

48.—Besides the foregoing necessities for the growth of vegetation in a chemical and mechanical point of view, there is one more, namely, the quantity of Carbonic Acid and Ammonia, or Nitrogen, which can be placed within its reach, and which is just as important a considera-tion as the others.

49.—The atmosphere affords an inexhaustible source of Carbonic Acid; rain water also contains both Carbonic Acid and Ammonia,

but the chief supply is derived from decaying manure or humus, both of Ammonia and of Carbonic Acid.

50.—Carbonic Acid (CO_2) is absorbed by the leaves of plants from the air. The Carbon is assimilated by them in their woody and leafy tissues, the Oxygen is released, but perhaps its greatest importance with regard to vegetation is due to its solvent power. Thus Lime might exist as the insoluble Carbonate, and be useless as far as appropriation and nourishment to a plant were concerned; but if Carbonic Acid were afforded, and the Bi-carbonate thus created which is soluble, the Salt could then be absorbed into the plant by the spongioles of the roots. It is the same with the other saline or mineral ingredients of the soil.

51.—Nitrogen is derived from Ammonia in the atmosphere, and from Carbonate of Ammonia, in decaying organic matters. It is a most important ingredient in the formation of all food, and of the blood of the animal frame. For every 100 parts of Carbonic Acid absorbed by the surface of the leaves, the plant receives from the atmosphere somewhat more than one part of Ammonia.

52.—The chief function of decaying manure, is to afford Ammonia and Carbonic Acid, which, either by themselves or acting as solvents for the mineral portions of the soil, supply nourishment. The constituent parts of Ammonia (NH_3) are Nitrogen and Hydrogen, and of Carbonic Acid (CO_2) Carbon and Oxygen, and accordingly we find, by the ultimate Analysis of the chief ingredients of manures, that these are contained in the following quantities:

	CARBON.	HYDROGEN.	OXYGEN.	NITROGEN.	ASHES.
Oats,	50·7	6·4	36·7	2·2	4·0
Wheat Straw,	48·4	5·3	38·9	0·4	7·0
Potatoes,	44·0	5·8	44·7	1·5	4·0
Turnips,	42·9	5·5	42·3	1·7	7·6
Hay,	45·8	5·0	38·7	1·5	9·0
Pea Straw,	45·8	5·0	35·6	2·3	11·3
Ox-blood,	51·96	7·25	21·30	15 07	4·42
Solid Cow Manure,	44·0	5·84	34·17	3·59	12·40
Ditto Horse ditto,	38·7	5·1	37·7	2·2	16·3
Mixed ditto fermented,	35·8	4·2	25·8	2·0	32·2

That they also supply the mineral ingredients as well as the chemical salts, formed by the combination of the above elements, with the

bases of the various inorganic substances, may be seen from the following table:

		Urine.			Bones.			Dung.		Urine.	Peat.
	Night Soil.	Human.	Cow's.	Guano.	Ox Bone.	Human Bones.	Bear Bones.	Cow's.	Horse's.	Horse's.	Charred Peat.
Water,	84·5	93·3	65·	......	2·45	·25	......	......	......	94·	......
Muriate, (Soda)	4·0	·44	......	......		......	......	......	......	......	......
Sulphate, (Soda)	2·0	·31	......	3·8	......	......	......	......	......	......	6
Phosphate, (Soda)	......	·27	....	......	......	·92	1·34	......	......	......	
Carbonate, (Soda)	......	......	......	......	......	......	......	......	......	3·3	......
Phosphate of Magnesia,	2·0	......	......	2·6	2·05	1·05	·50	10·0	36·25	......	......
Fluoride, (Lime)	......	......	......	......	......	1·0	2·12	1·5	......	......	......
Phosphate, (Lime)	4·0	......	3·	14·3	58·35	52·26	62·11	10·9	5·0	......	......
Oxalate, (Lime)	......	......	......	7·0	......	......	......	......	......	......	......
Carbonate, (Lime)	......	......	......	......	3·85	10·21	13·24	......	18·75	1·1	40
Sulphate, (Lime)	......	......	....	......	......	......	12·25	3·1	......	......	12
Elements of Urea, (Ammonia)	...	3·0	4·	9·0	......	......	......	......	......	·7	......
Phosphate, (Ammonia)	......	·16	......	6·	......	......	......	......	......	......	......
Muriate, (Ammonia)	......	·15	7·5	4·2	......	......	......	......	......	......	......
Other Salts, (Ammonia)	......	1·8	......	......	......	......	......	......	......	......	......
Carbonate, (Ammonia)	......	......	2·0	......	......	......	......	......	......	......	......
Oxalate, (Ammonia)	......	......	....	10·6	......	......	......	......	......	......	......
Sulphate, (Potash)	......	·39	6·	5·5	......	......	......	......	......	......	......
Muriate, (Potash)	......	......	7·5	......	......	......	......	......	......	......	......
Carbonate, (Potash)	......	......	2·	......	......	......	......	......	......	......	......
Phosphate of Iron,	......	......	......	......	......	....	......	8·5	......	......	....
Earthy matter, Silica, &c.,	......	·1	....	4·7	......	1·05	4·24	63·7	40·0	......	32
Animal substances with a little Iron and Water,	......	......	......	32·3	......	1·01	......	2·3	......	......	3
Cartilage or Gelatine,	......	....	......	......	33·3	32·25	4·20	......	......	......	....
	96·5	99·92	97·0	100·0	100·	100·0	100·0	100·0	100·0	99·1	93·

SECTION II.

ANIMAL ECONOMY.

1.—Having considered the nature of the soil and of manures, as well as that of the growth of the soil or food, let us now consider the nature of the animal economy to which these are subservient.

2.—There are two species of nourishment supplied to the human frame. One the food we eat, the other the air we breathe. The constituents of the first are chiefly Carbon, Hydrogen and Nitrogen. Of the second, the constitution is Nitrogen 79, Oxygen 21, and a small variable quantity, from $\frac{1}{1000}$ to $\frac{1}{2000}$, of Carbonic Acid, besides a small quantity of Ammonia, and mere traces of combustible gases.

3.—The heart is the main-spring of life, and acts upon the blood, which it propels through the lungs. The lungs, as the scene of the respiratory process, consist of an arborescent ramification of tubes, which become continually smaller, the last twigs of which end in minute sacs or bladders, called air cells. By the bronchi and trachea they communicate with the cavities of the mouth and nose. The walls of the air cells are penetrated by a close net-work of very minute blood-vessels, so that the air in the cells is only separated from the blood by a membrane excessively thin, and with the blood in these vessels, the air comes into immediate contact through the fluid, which, proceeding from the blood, moistens the walls of the blood-vessels.

4.—Thus an immense surface of the venous blood which, in its circulation through the remotest parts of the human frame, has become vitiated and of a dark nearly black-red colour, is brought into contact with the respired air, and a combination takes place between their respective constituents. The Carbon and Hydrogen of the blood combine with the Oxygen of the air, forming respectively Carbonic Acid *(CO_2)* and water *(HO)* which are thrown off by the lungs and skin.

5.—As the combination of a combustible substance, such as Carbon or Hydrogen, with Oxygen, is under all circumstances the cause of heat, there arises hence the animal heat which pervades the frame, and is of such consequence to life, and where this process of combination is rapid, *i. e.*, where respiration is quick, more heat is developed, and more Carbon and Hydrogen consumed.

As no part of the Oxygen taken into the system of an animal is given off in any other form than combined with Carbon or Hydrogen, and as in a state of health the Carbon and Hydrogen so given off are replaced by those elements in the food, it is evident that the amount of nourishment required by an animal for its support, must be in a direct ratio with the quantity of Oxygen taken into its system by the lungs.

6.—It is ascertained that in all climates the temperature of the body of man remains the same, that is, the blood of the inhabitant of the arctic circle has a temperature as high as that of the native of the South. But the animal body is a heated mass, which bears the same relation to surrounding objects as any other heated mass. It receives heat when the surrounding objects are hotter, it loses heat when they are colder than itself.

7.—If, owing to external circumstances, it parts with much of its heat, this must be compensated by increased mutual action between the lungs and blood. And it is so accordingly we find in the fact, that the fruits used by inhabitants of Southern climes, who live in a warm atmosphere, and whose respiration is comparatively slow, do not contain in a fresh state more than 12 per cent. Carbon, while the blubber and train oil, which feed the inhabitants of Polar regions, contain 66 to 80 per cent. of that element. In like manner, it is obvious that the amount of heat created or liberated in the system, must increase or diminish with the quantity of Oxygen introduced in equal times by respiration. Those animals, therefore, which respire frequently, and consequently consume much Oxygen, possess a higher temperature than others, which, with a body of equal size to be heated, take into the system less Oxygen. The temperature of a child (102°) is higher than that of an adult (99·5). That of birds (104° to 105·4) is higher than that of quadrupeds (98·5 to 100·4) or than that of fishes or amphibia, whose proper temperature is from 2·7 to 3·6 higher than that of the medium in which they live.

8.—We may thus observe the different manner in which the constitution is affected in a hot, compared with a cold, climate. Where the air is warmer, and less dense, it contains less Oxygen. It also contains more aqueous vapour, which occupies the place of what in a colder temperature would be air. Therefore, on the whole, an equal volume of air in frosty weather contains more Oxygen than in summer, and hence the exhausting heat of tropical climates, the number and depth of the respirations in a cold being both increased. Hence also

the diminished desire or necessity for solid food in a hot climate; the aid derived from even moderate exercise, or exposure to the open air in a carriage or on the deck of a ship, which, by increasing the loss of heat, compels us to eat more than usual, and stimulates the respiration.

9.—When the food is not properly digested or assimilated, so as to supply the necessary Carbon and Hydrogen to the blood, these materials have to be supplied from other sources, to meet the requirements of the Oxygen taken in by the lungs, and emaciation from consumption of the tissues and muscles of the system, takes place.

10.—Intimately dependant on the action of the intestines, are those of the liver and kidneys. In the lower orders of creation, the size of the liver is in an inverse ratio to the undeveloped or imperfectly developed organs of respiration; and even in the higher classes of animals, a small lung usually corresponds to a large liver in healthy individuals. The liver roughly sketched is the magazine for the matters destined for respiration: it is the workshop in which they receive the shape and quality fitted for the production of animal heat. The liver is small, with a large well-developed lung. The quicker and more perfectly the fuel is consumed, the less of it accumulates in the magazine for fuel, the size of which has the most definite relation to the rapidity of the consumption. If the lungs do not act with sufficient power to throw off all the Carbon of the system, additional work is thrown upon the liver. Hence a cause of diseased liver.

11.—The kidneys, in like manner, it is well known by experienced physicians, are the regulators of the respiratory process. The lower intestine is an organ of secretion—the chimney of the organism. The constituents of the excreta are, as it were, the soot separated from the blood by this intestine; while the urine contains those constituents of the smoke, so to speak, which are soluble in water or in alkaline or acid liquids. The urine of the horse and cow, moreover, contains a substance in considerable quantity which, when acted on by acids, yields a pitchy matter, quite similar in its aspect to tar; and as the most remarkable product, Carbonic Acid, or Hydrated Oxide of Phenyle, the chief ingredient of common wood, tar, and of creosote. This shows that the illustration of the furnace is a true one, since we actually obtain, as the products of imperfect oxidation or combustion in the body, substances which are formed by the imperfect oxidation or combustion of organic matter in furnaces.

12.—It being evident, then, how important to health is a proper performance of the process of combustion in the system between the air

taken into the lungs and the blood, (or in other words the food taken into the stomach), it becomes evidently of the highest importance, that both air and food should be of the best quality, or of that quality best adapted to the objects for which they are destined.

13.—Let us consider Air first. It is composed, in its ordinary state, by volume as before stated, of 79 Nitrogen, 21 (or more accurately 20·9) of Oxygen, about $\frac{1}{2000}$ of Carbonic Acid, (or by weight ·75 of Carbonic Acid in 1000 parts by weight of air) and a trace of Ammonia. When expired from the human lungs, however, it is found to contain from 3·5 to 5, and even as far in very deep respiration as 9 volumes per hundred of Carbonic Acid, and from 16·5 and 15 in the former to 11·5 and 11 volumes of Oxygen in 100 parts in the latter case. The amount of Oxygen is, therefore, diminished to the extent of $\frac{1}{5}$ or $\frac{1}{4}$, while the Carbonic Acid is increased above 100 times by respiration.

14.—In a state of rest we may reckon the number of respirations of a human being per minute as 15, at each of which he expires 30 to 31 cubic inches of air. In the 24 hours this would amount to $15 \times 60 \times 24 \times 30 = 380$ cubic feet, which, at 5 per cent. of Carbonic Acid, would give the amount of Carbonate Acid expired by one person in 24 hours as 19 cubic feet.

It is not *impossible* to breathe again air in this state of vitiation, and the amount of Carbonic Acid in it may even be increased to 10 per cent., but not beyond this without death ensuing. But as far as personal comfort is concerned, 1 per cent. of Carbonic Acid even, is appreciated sensibly, and causes uneasiness. In general the *percentage* of Carbonic Acid diminishes when the respirations are quick, but the *whole amount* of Carbonic Acid expired in a given time is much greater. Thus it is seen that both deeper and more rapid respiration separate in a given time more Carbonic Acid from the blood, or cause a more effectual decarbonization of it, and if more Carbonic Acid is given off, more Oxygen is received in return. If Carbonic Acid exist in the air, it presents an obstacle to the separation of that Gas from the blood and to the absorption of Oxygen.

15.—The living in low situations, in which the air is stagnant; in damp places, where Carbonic Acid is produced by decay, or in air saturated with moisture at a high temperature, has long been recognized by physicians as the proximate cause of many diseases. In sleeping rooms where plants grow, which during the night absorb Oxygen and give out Carbonic Acid, in close rooms in which combustion goes on without ventilation, or in over-crowded rooms and barracks, the

air acquires the composition of expired air, and the respiratory process is thus essentially endangered. The altered state of the air from respiration may be shown in a lighted room by the elongation of the flame of a candle and by its burning dimly. In a closed space, 8 feet high, 9 long and 8 wide, a man could not breathe for 24 hours without uneasiness. At the end of that time, the air would have the composition of expired air, and if the person remained longer in the same air, a morbid state, and finally death, would ensue. 8 × 8 × 9 gives 576, or say 600 cubic feet for one person.

16.—In the Hall of the Chamber of Deputies at Paris, which has a cubical content of 180,000 feet, M. Leblanc found that, when 600 persons were present, and with a ventilation of 396,000 cubic feet per hour, the air flowing out contained, notwithstanding, one part of Carbonic Acid by *weight* in 400, which is $2\frac{1}{2}$ or 3 times more than is contained in pure air, (*viz.*, ·75 in 1000.) This gives the *ventilation* of 660 cubic feet per individual per hour; and if this had been rendered efficient, it should have been $660 \times 2\frac{1}{2} = 1{,}650$ cubic feet per hour for each person.

Suppose that each of those 600 persons had during 24 hours expired 19 cubic feet of Carbonic Acid, as before stated; and that the air were required to be kept at its full state of purity, or 1 in 2,000 by volume. Then $600 \times 19 \times 2{,}000 = 22{,}800{,}000$, the total amount of ventilation which would be required in 24 hours, or $22{,}800{,}000 \div 600 \div 24 = 1{,}584$ cubic feet per hour for each person.

(This nearly corresponds with the foregoing calculation—Liebig, notwithstanding says, that 216 cubic feet per hour of pure air for every adult, is a proper supply, but that it is usual to allow one-half more. In all 324 cubic feet only for each person.)

17.—The means employed by Chemists to determine the quantity of the constituents of Air, are very simple. Hydrated Potash, or Caustic Potash, absorbs more than 100 times its volume of Carbonic Acid, and it is easy to see that the increase of weight in a tube filled with Potash, through which we conduct slowly a cubic foot of dry air, informs us exactly how much Carbonic Acid this cubic foot of air contained. Just as Carbonic Acid is absorbed by Potash, Oxygen is absorbed by red-hot Copper; and if we cause a cubic foot of dry air, purified from Carbonic Acid, to pass through a red-hot tube filled with Copper turnings, all the Oxygen remains with the Copper, and the gain of weight of the tube gives exactly the amount of Oxygen in this cubic foot of air, the total weight of which is also known.

Or it may be done thus:—If we introduce into a glass tube, closed at the upper end, graduated in equal divisions, and filled with dry expired air, the lower open end being immersed in Mercury, about $\frac{1}{40}$th of the volume of the air of strong solution of Potash, the volume of the air instantly diminishes, the Carbonic Acid present being absorbed by the Potash. If now we add to the Potash a concentrated solution of Pyrogallic Acid, about $\frac{1}{2}$ the volume of the Potash, the mixture absorbs the Oxygen as rapidly as red-hot Copper does; the volume again diminishes to a degree exactly corresponding with the amount of Oxygen present; and the residue is Nitrogen.

18.—Thus much for Air and its purity. Next as to Food. The constituents of the food, consumed by men and by animals, may be divided into three classes, *viz.*—1*st.*—The *plastic materials,* or those which go to the formation of bones, muscle, &c., also called "sanguigenous" and "nitrogenous?"

2ndly.—The non-nitrogenous, or those which furnish the materials for *respiration* in the blood, Carbon and Hydrogen.

3rdly.—The incombustible constituents, or the salts of the blood, which are necessary to render the two former digestible, and thus conducive to their respective ends.

The substances called "plastic" are six, *viz.*—

1. Animal Albumen,
2. „ Fibrine,
3. „ Caseine,
4. Vegetable Albumen,
5. „ Fibrine,
6. „ Caseine,

and from these Nitrogeno-sulphurized substances in the process of nutrition, the chief constituent of the blood, and in the vital process all the tissues of the animal body, are formed.

19.—If the growth or increase of mass in the animal body, the development of its organs, and their re-production proceed from the blood, that is the constituent parts of the blood, only those substances can serve these purposes which contain the elements of blood in a form, and with qualities such that they can be converted or transformed into blood.

20.— Blood, or the serum of blood, coagulates when heated, and the coagulating substance is the albumen of blood, *Animal Albumen.* An exactly similar substance, except that it contains a little more Sulphur, is the well-known Albumen or white of an egg, which coagulates also

on *heating*. Both contain Sulphur and Nitrogen. For every equivalent of the latter both contain eight equivalents of Carbon, and they also agree in their quantity of Hydrogen.

21.—If we reflect on the important office of the Albumen in an egg from which, by the influence of heat, and Oxygen penetrating through the pores of the shell, all the parts of the animal body, feathers, claws, fibrine, membranes, cells, blood, corpuscules, the material of the blood-vessels and nerves and bones, are developed, it will become obvious that Albumen is the foundation, the starting point, of the whole series of peculiar tissues, which constitute those organs which are the seat of all vital actions.

Albumen is a constituent of the brain and of the nerves, of the liver, kidneys, spleen, and all glands. The continuance of life is indissolubly connected with its presence in the blood, that is in the nutrient fluid. Strictly speaking, only those substances are nutritious articles of food which contain either albumen, or a substance capable of being converted into albumen.*

22.—Looking at alimentary substances from this point of view, we obtain a knowledge of a natural law of the most admirable simplicity.

Flesh, the most nutritive of all kinds of food, has been found by Chemical Analysis to contain the same elements in the same proportion as the Albumen of blood. These two bodies stand to each other in the same relation as fresh albumen and coagulated albumen. In composition *Fibrine* is nothing more than Albumen of blood solidified and in an organized form. The difference, if any, is so minute, that an analysis of the muscular fibre does not differ more from one of albumen of blood than two analyses of the latter body do from each other.

In flesh, therefore, we have one of the first conditions for the production of blood. A fact which may also be confirmed by our knowledge of the nutritive process in carnivora and by a simple experiment, *viz.*, the decomposition of muscular fibre when left exposed to the air and covered with water, under which circumstances it coagulates into a white solid mass, identical in all its properties with the coagulated Albumen of blood.

23.—*Animal Caseine* is the curd obtained from Milk. Milk, when fresh, is alkaline, as may be shown by its restoring the color of reddened Litmus Paper. In this state the Caseine is held in solution by the free Alkalis and Alkaline Phosphates in it, but when an *Acid* is

* NOTE.—The most delicate tests for Albumen are the Perchloride of Mercury or Corrosive Sublimate *(Hg, Cl_2)* and Ferro-cyanide of Potassium *(Kcfy.)*

added (as rennet) neutralizing the Alkali, the caseine is separated in its naturally insoluble state.

24.—Caseine is, in its properties, distinct from Albumen and Fibrine. It may be heated to boiling without coagulating. It is easily coagulated in the cold by dilute Acetic Acid, and when separated, its thick flocculent masses, after boiling with water, dissolve with extreme facility in weak alkaline liquids; a property by which Caseine is very essentially distinguished from coagulated Albumen and muscular fibre. It contains, like Albumen, however, Sulphur and Nitrogen; and the absence of every other nitrogenous compound in Milk, renders it perfectly certain that from Caseine alone, the chief constituent of the young animal's blood, as well as its muscular fibres, membranes, &c. are formed in the first stage of its life.

25.—From the foregoing we can understand the process of nutrition of the carnivora and of the sucking young of mammalia. The carnivora live on the flesh and blood of those animals which live on grass and grain. This nourishment is, in its chief constituent, identical with the chief constituent of the blood of the carnivorous female, from which its organs are developed; and its young derive their blood directly from herself.

26.—The process of graminivorous animals, however, appears at first sight very different. Their food consists of vegetables, which, in form and quality, have not the smallest resemblance to milk and flesh. It has been proved that all such parts of plants as serve for food to animals contain certain constituents, easily distinguished from others by burning with the smell of burnt wool. It is found that animals require for their support less of any vegetable food in proportion as it is richer in these peculiar matters, and that they cannot be nourished by vegetables in which these matters are absent.

27—These important products of vegetation are especially abundant in the seeds of the different kinds of grain, and of peas, beans and lentils; in the roots and juices of what are commonly called vegetables; they exist, however, in all plants without exception, and in every part of plants, in larger or smaller quantity. They may be reduced to the three following easily distinguishable substances.

28.—When the newly-expressed juices of vegetables are allowed to stand, a separation takes place in a few minutes. A gelatinous precipitate, commonly of a green tinge, is deposited, and this, when acted on by liquids which remove the coloring matter, leaves a greyish white substance, well known to druggists as the deposit from vegetable juices.

The juice of grasses is especially rich in this constituent, but it is most abundant in the seeds of wheat and of the cerealia generally. It may be obtained from wheat flour by a mechanical operation in tolerable purity, by tying up some flour in a small linen bag, and repeatedly washing till the water is no longer colored white. The substance remaining is called "*gluten*," but the glutinous property belongs in part to an oily substance present in a small quantity. Its appearance is somewhat similar to masticated India-rubber. It corresponds to *Animal Fibrine.*

29.—The second nitrogenized substance remains dissolved in the juice after the separation of the Fibrine. When the clarified juice of nutritious vegetables, such as cauliflower, asparagus, mangel wurzel, or turnips, is made to *boil*, a coagulum is formed, which it is absolutely impossible to distinguish from the substance which separates as coagulum, when the serum of blood, or the white of an egg diluted with water, are heated to the boiling point. This corresponds with the *Albumen.*

30.—The third of these important vegetable principles, is chiefly found in the seeds of peas, beans, lentils, and similar leguminous seeds. It may be extracted from their meal by cold water and kept in solution. In this solution it resembles the others, but is distinguished from them in this, that its solution is not coagulated by heat. When the solution is heated or evaporated, a skin forms on its surface, and the addition of *an acid* causes a coagulum, just as in animal milk with *Caseine.*

31.—The Analysis of these three vegetable principles has led to the interesting result that they all three contain Sulphur and Nitrogen, and the other constituents in the same proportion, and what is still more remarkable, that they are identical in composition with Albumen, containing the same elements, in the same proportion as that chief constituent of the blood.

32.—How admirably simple, says Liebig, after we have acquired a knowledge of this relation between plants and animals, appears to us the process of formation of the animal body, the origin of its blood and of its organs. From Carbonic Acid, Water, and Ammonia, that is from the constituents of the atmosphere with the addition of Sulphur and of certain constituents of the crust of the earth, plants produce the blood of animals; for the carnivora consume, in the blood and flesh of the herbivora strictly speaking, only the vegetable substances on which the latter have fed. It is obvious that the animal organism produces its blood only in regard to the form of that fluid, and that nature has denied to it

the power of creating blood out of any other substances, save such as are identical in all essential points with Albumen, the chief constituent of blood.

33.—If we compare the three nitrogeno-sulphurized vegetable products with the Fibrine of flesh, the Albumen of blood, and the Caseine of Milk, on reference to their physical character, we find that the *gluten* of wheat flour has the closest resemblance to the *Fibrine* of flesh; that that constituent of vegetable juices which is *coagulated by heat* is absolutely not distinguishable from the *Albumen* of blood; and lastly, that the chief constituent of the seeds of the leguminosæ agrees, in all its properties and behaviour, with the *Caseine* of Milk.

34.—These different substances, whether of animal or vegetable origin, yield in processes of oxidation the same products; a fact which chemistry regards as a proof that their elements are also arranged in the same way. When such compounds are acted on by strong Potash, a part of their Sulphur is taken up by the Potash, and the Alkaline solution, by the presence of Sulphuret of Potassium, acquires the property of forming when a drop of solution of Sugar of Lead (Acetate of Lead) is added, an inky fluid colored by the Sulphide of Lead.

35.—There is indeed no part of an organ possessing a form or structure of its own, the elements of which are not derived from the Albumen of the blood. All organised tissues in the body contain a certain amount of Nitrogen. Many of the physical properties of the organs or tissues, it is true, depend on the presence of their non-nitrogenous constituents, *viz.*, of water and fat. But in these parts water and fat are only mechanically absorbed as in a sponge, or enclosed in drops as fat is in cells, and they may be removed by mechanical pressure or by solvents, without in the least affecting the structure of the parts. They do not, therefore, belong to the plastic constituents of the body, or of the food.

36.—The *Plastic materials* are distinguished by the Nitrogen and Sulphur they contain, but the food of all animals contains, besides, a certain amount of substances devoid of Nitrogen and of Sulphur, *viz.*, the non-nitrogenous or respiratory Sugar of Milk, which may be obtained from the whey of milk by evaporation, and which of course forms an essential part of the food of carnivora, has very analogous substances in the food of the herbivora, *viz.*, starch, cane and grape sugar, gum, &c. These are non-nitrogenous, so also are the fat in flesh and in milk in the shape of butter.

37.—A most universally diffused substance in the vegetable kingdom, and in the food of the herbivora which, in the process of their nutrition, plays the same important part as Milk Sugar does in that of the carnivora, is *Starch*, which appears at first sight the most remote from Milk Sugar in its properties. If potatoes, unripe apples, or pears, chestnuts, acorns, radishes, arrow-root, the pith of certain palms, wheat and other grains, be rubbed down, and the paste washed with water on a fine sieve, the white and turbid fluid which passes through deposits Starch in the form of a snow-white very fine powder.

38.—Sweet fruits and vegetable juices owe their sweet taste to three kinds of sugar, of which two are crystallizable, while the third is always soft or of syrupy consistence. This last kind occurs in most fruits. The other two are Grape and Cane sugar. Beet-root and Carrots contain the same kind of Sugar, as the juice of the sugar-cane. Honey contains the same kind as Grapes.

39.—Dried Grape Sugar has the same composition as crystallized Milk Sugar; and in its action on metallic oxides, such as Oxide of Silver, Oxide of Copper and Peroxide of Iron, and on Indigo as well as in other properties, it agrees exactly with Milk Sugar.

The formula for Milk Sugar is $C_{12}\ H_{12}\ O_{12}$, that of Cane Sugar is $C_{12}\ H_{11}\ O_{11}$, the difference being merely one equivalent of water HO, but by contact with ferments or acids it takes up into its composition this one equivalent of water, and passes readily into Grape Sugar.

40.—In like manner Starch, Paste or Jelly, when mixed with a hot infusion of malt, becomes at once fluid, and after forming a substance like gum, called dextrine, becomes finally entirely changed into Grape Sugar. A similar conversion of Starch is effected by the saliva, during the process of digestion, and it is transformed into a substance which, in its composition and chief properties, agrees with Sugar of Milk.

The amount of Starch in the flour of different kinds of grain, in peas, beans, and potatoes is very large. Wheat and rye flour contain from 60 to 66 per cent; barley and lentils 40 to 50; Maize flour about 78; rice as much as 86; potatoes (dry) above 70.

41.—The fat of butter and that of flesh contain Carbon and Hydrogen (the respiratory materials) very nearly in the same relative proportion as Starch and the various Sugars. These differ from fat chiefly in containing more Oxygen. For the same quantity of Carbon, fat contains nearly 10 times less Oxygen than Starch, &c., and it is therefore easy, by adding Oxygen, to convert in our calculations a given

amount of fat into Starch. In this way we find that 10 parts of fat correspond to 24 of Starch, and changing by this rule the fat of butter and of meat into their equivalent proportions of Starch also the Milk Sugar of Milk into Starch, by deducting from it the extra equivalent of water, we obtain the following proportions in general numbers of Plastic to respiratory materials in the chief kinds of food:

	Plastic.		Non-nitrogenous or Respiratory, calculated as Starch.
Cow's Milk,	1	to	3
Human Milk,	1	"	4
Lentils, Beans and Peas,	1	"	2½
Wheat, Rye, Barley, Oats,	1	"	5½
Potatoes,	1	"	from 8 to 11
Rice and Buckwheat,	1	"	12½
Fat Mutton,	1	"	2 7/10
Fat Pork,	1	"	3
Beef,	1	"	1 7/10
Hare,	1	"	0 2/10
Veal,	1	"	0 1/10

42.—By a due admixture of these articles, we can obtain a diet of a composition analogous to that of milk or wheaten bread. By the addition of fat pork or bacon to peas, &c., of potatoes to beef; of fat bacon or ham to veal; of rice to mutton, we increase in each case the proportion of non-nitrogenous matter. The same result is obtained by the use of fermented liquors, which, when taken with lean flesh and little bread, yield a diet approaching to milk, and with fat meat one approaching to rice or potatoes in the relative proportions of plastic and non-nitrogenous constituents.

43.—Innumerable observations made during centuries have demonstrated beyond a doubt that different forms of food are extremely unequal in regard to the production and restoration of the nervous and mental manifestations in the human frame. That wheat surpasses rye, that rye surpasses potatoes and rice, and that flesh surpasses all other food in reference to these effects. Thus a horse fed on potatoes cannot perform any thing like the same amount of work as one fed on hay and oats, and the power of daily labour available in a man may be measured by the quantity of the plastic or sanguigenous constituents contained in the flesh and bread he consumes. For all the Albumen of the blood is derived from these, and all the organized tissues of the frame which in any way manifest force, from the Albumen.

44.—The diet of the working man should contain for four parts of non-nitrogenous constituents one part of plastic nutritive matter, for this

is the relative proportion which nature has herself appointed in the human milk; so also when a child deprived of the benefit of receiving the necessary supply from the mother is fed on cow's milk, which contains a larger proportion of plastic matter; Milk Sugar (or Cane Sugar) should be added to the cow's milk; or when it is fed on flour paste, cow's milk should be added, as experience has long ago taught us, in order to obtain the same effects as from the mother's milk.

45.—Let it now be observed, after noting the difference between the chemical constitution and the duties of the plastic and the respiratory materials, the nitrogeno-sulphurized, and the non-nitrogenous substances, how necessary to the animal economy this distinction is, and how incapable each is of performing the part allotted to the other.

46.—Almost all compounds of Nitrogen are, compared with other bodies, difficultly combustible, and are never regarded as fuel because when they do burn they develop only a low degree of heat. Phosphorus takes fire at the heat of the body, and is easily oxidized by dilute Nitric Acid; but the Phosphuret of Nitrogen, a white body like chalk, only takes fire at a red heat and in Oxygen gas, but does not continue to burn, and is not attacked by dilute Nitric Acid. Ammonia (NH_3,) a compound of Nitrogen with Hydrogen, contains in two volumes three volumes of Hydrogen, but in spite of this large proportion of an element so inflammable and combustible, Ammonia cannot be set fire to by a red-bot body, and even in pure Oxygen it does not continue to burn.

47.—If we compare, then, the amount of the plastic matters daily consumed with that of the Oxygen in respired air, consumed in the same time, we find that the combustible elements of the former are very far from sufficing to convert into Carbonic Acid and Water the whole of the Oxygen which has entered the blood. The animal body takes up far more Oxygen; the horse, for example, five times, the pig six times as much as would be required for the most perfect combustion of the plastic matter in the food. If, therefore, the combustible elements of the plastic constituents of food, served for the production of the animal heat, the whole amount of these substances consumed by the horse in his hay and oats, by the pig in his potatoes, would only suffice to support their respiratory process, and consequently their animal heat, in the horse for 4½ hours, in the pig for four hours daily; or if confined to plastic food, they would require to consume five or six times as much of it.

48.—But the Albumen of the Alkaline blood is like Nitrogen. Its power of combining with Oxygen is very small, compared with that of the other and non-nitrogenous constituents of the blood. Without the powerful resistance which the nitrogenised constituents of the body, in consequence of their peculiar nature as compounds of Nitrogen, oppose beyond all other parts to the action of the air, organic life could not subsist. If the Albumen of the blood, which is derived from the plastic portion of the food, possessed in a higher degree the power of supporting respiration, it would be utterly unfit for the process of nutrition.

49.—As long as the blood contains, besides Albumen, other substances which surpass it in attraction for Oxygen, so long will the Oxygen be unable to exert a destructive action on this, the chief constituent of the blood; and the significance of the non-nitrogenous part of the food is thus made clear. Starch, Sugar and Fat serve to protect the organized tissues, and in consequence of the combination of their elements with Oxygen to keep up the temperature of the body.

The sulphurized and nitrogenised constituents of food determine the continuance of the manifestations of force, the non-nitrogenous serve to produce heat, the former are the builders of organs and organized structures and the producers of force; the latter support the respiratory process; they are *materials for respiration.*

50.—We now come to the *incombustible constituents* or *salts of the blood.* Hitherto it has been shown that certain constituents of seeds, roots, tubers, herbs, fruits and flesh, have the power of supporting the processes of nutrition and respiration; and it will appear as a very striking contradiction when it is stated that no one of these substances by itself, neither Caseine alone, nor the substance of muscular fibre, the Albumen of eggs or of the blood, nor the corresponding vegetable products, are able to support the plastic or formative processes, that neither starch, sugar, nor fat can sustain the process of respiration. Nay, it may excite still greater astonishment to add, that these substances, even when mixed, no matter in what proportions, are destitute of the property of digestibility, without the presence of certain other substances; so much so indeed, that if these other conditions be excluded, the above named compounds are utterly unable to effect the continuance of life and of the vital phenomena.

51.—Numerous experiments made upon living animals have proved this by ending in the death, as from starvation, of the creatures upon

whom the trial was made, who after a few days refused, even under the severe pangs of hunger, to take a food which instinct, at first deceived, told them was as truly indifferent or useless for the purposes of nutrition as the eating of stones.

52.—On the other hand it is a fact, confirmed by the experience of thousands of years, that flesh and bread, either separately or mixed together, as well as the milk of animals, suffice to support life in full vigor, without the necessity of adding any other substance whatever; and hence it follows necessarily that these articles of food, flesh, bread, and milk, and likewise the plants or parts of plants consumed by the herbivorous animal, must contain, and in the due proportion, those other conditions, the presence and co-operation of which is indispensably necessary for the processes of digestion and nutrition.

53.—These necessary matters, essential to the organic processes, by the presence of which the plastic constituents of food and the respiratory materials acquire those properties which render them fit and proper for the support of life, are the incombustible constituents or the salts of blood. They are of the same nature and quality in all animals, and omitting such as are accidental or variable, they are Phosphoric Acid, Alkalies, (Potash and Soda), Alkaline Earths, (Lime, Magnesia), Iron, (oxidized), and Common Salt (Chloride of Sodium.)

54.—All these matters before they became parts of the blood, were constituents of the food of man or of the fodder of animals. If then it be true that these substances take or have taken a necessary and determining part in converting the constituents of food into constituents of the body, it follows that no kind of food can sustain life, in which these substances are wanting; that all kinds of food for man or animals, which possess full nutritive power, must contain these bodies in the proportions adapted to the formation of blood, and that we can deprive the food of its sanguific properties, if we deprive it of these conditions, indispensable to those peculiar properties.

55.—Analytical Chemistry has furnished the strictest proofs of the justice of these conclusions, by showing that turnips, potatoes and the herbs eaten by the herbivora, contain the same incombustible constituents as their blood, and very nearly in the same proportion.

The constituents of the ash of the blood of the graminivorous animals are identical with those of the ash of grain; the incombustible constituents of the blood of men and of such animals as consume a mixed food are the constituents of the ashes of bread, flesh and vegetables. The

carnivorous animal contains in its blood the constituents of the ash of flesh.

	Ashes of				
	Blood of Sheep.	Blood of Ox.	Cabbage.	Turnips.	Potatoes.
Phosphoric Acid,	14·80	14·043	13·7	14·18	16·83
Alkalis,	55·79	59·97	49·45	52·0	55·44
Alkaline Earths,	4·87	3·64	14·08	13·58	6·74
Carbonic Acid,	19·47	18·85	12·42	8·03	12·00

The ashes are calculated in 100 parts after deducting the common Salt and Iron; the loss or deficiency in 100 parts consists of accidental constituents, as Sulphuric Acid, Silica, &c.

	Ashes of		
	Blood of Dog.	Ox flesh.	Blood of Pig.
Phosphoric Acid,	36·82	42·03	36·5
Alkalis,	55·24	43·95	49·8
Alkaline Earths,	2·07	6·17	3·8
Silicic and Sulphuric Acid,	5·87	7·85	9·9

	Ashes of		
	Peas.	Blood of Fowl.	Rye.
Phosphoric Acid,	34·01	47·26	47·29
Alkalis,	45·52	48·41	37·21
Alkaline Earths,	9·61	2·22	11·60
Silicic and Sulphuric Acid,	10·86	2·11	3·90

56.—The blood of all animals has invariably an Alkaline character, arising from the presence of a free fixed Alkali. All articles of food which alone, as bread and flesh, or when mixed with vegetables, are capable of sustaining the process of sanguification and nutrition, contain Carbonic Acid, or Phosphoric Acid and Alkalis; the two latter in such proportion, that if we suppose them dissolved, the Alkalis invariably predominate.

57.—This Alkaline condition is not only essential to life, as was proved in the case where dogs were starved to death who were fed on animal fibrine, or Caseine, or on flesh boiled and pressed out, *i. e.*, in great measure deprived of its Alkalis, but on examination an *Acid* state of the blood appears to be utterly irreconcileable with the functions which it has to perform in the nutritive and respiratory processes. The free *Alkali* gives to the blood a number of very remarkable properties. By its means, the chief constituents of the blood are kept in their fluid state; the extreme facility with which the blood moves through the minutest vessels is due to the small degree of permeability of the walls of these vessels for the Alkaline fluid. The free Alkali acts as a resistance to many causes which, in the absence of the Alkali, would coagulate the Albumen. The more Alkali the blood contains, the higher is the temperature at which its Albumen coagulates; and with a certain amount of Alkali, the blood is no longer coagulated by heat at all. On the Alkali depends a remarkable property of the blood; that of dissolving the Oxides of Iron, which are ingredients of the coloring matter of the blood, as well as other metallic Oxides, so as to form perfectly transparent solutions.

58.—The free Alkali in the blood also exerts a very beneficial effect on the process of respiration ; a number of organic compounds acquire by contact with or in presence of a free Alkali, the power of combining with Oxygen (of burning), which alone they do not at all possess at the ordinary temperature of the air, or at the temperature of the body. Milk Sugar, and Grape Sugar in presence of a free Alkali, and with the aid of a gentle heat, deprive even metallic Oxides of their Oxygen. The Alkalis exert a precisely similar action in the blood; they promote and increase the combustibility of the respiratory matters; and if the Alkaline character of the blood be interfered with by the mixture of Acids which should have passed off as usual in the urine, a circumstance which occurs in cases of inflammation or fever, a change in the breathing takes place.

59.—The significance and importance of Phosphoric Acid in the vital process is obvious, when we remember that this Acid is a never failing ingredient of all the organized structures of the animal body.

The substance of muscular Fibre, the fibrine of blood, the pulmonary tissues, the liver and the kidneys, contain a certain amount of Phosphoric Acid in chemical combination. The ashes or incombustible ingredients of the fluids of the *flesh* are in all animals of the same nature and quality. They consist of Alkaline Phosphates, Phosphate of Potash and

Phosphate of Magnesia. The bones of the vertebrata contain more than half their weight of the Phosphates of Lime and Magnesia. The substance of the brain and the nerves contain Phosphoric Acid, coupled with a fat or with a fatty Acid, the Phosphoric Acid being partly in combination with an Alkali. The Phosphoric Acid contained in these tissues is derived from the blood. The blood contains, under all circumstances, a certain amount of Phosphoric Acid.

	Ashes of		
	Free Phosphoric Acid.	Alkaline Phosphates.	Earthy Phosphates.
Horse flesh,......	2·62	80·96	16·42
Ox flesh,.........	17 23	48·06	26·26
Ox brain,.........	16·57	74·41	9·02
Yolk of Egg, ...	36·74	27·25	34·7

60.—The formation and production of the organized structures cannot be imagined without an excess of Phosphoric Acid. In comparing the ashes of the *blood* of herbivorous, graminivorous, and carnivorous animals together, we observe, in the proportion of the Alkalis to the Phosphoric Acid, most extraordinary differences. The blood of the pig and of the dog contain 36 per cent., that of the fowl above 40 per cent., in that of oxen and sheep not more than from 14 to 16 per cent. of Phosphoric Acid. But in analysing the imcombustible ingredients of their *flesh*, it is impossible to distinguish by any difference of Phosphoric Acid that of the ox from that of the pig or dog, or to say which ashes have been obtained from the flesh of the carnivorous or of the herbivorous animal.

61.—The blood carries to all parts of the body the necessary Phosphoric Acid, and must, therefore, always contain a certain amount of that Acid; but the Phosphoric Acid plays no part in sanguification or in the functions of the blood, because its properties, as an Acid, entirely disappear in the excess of Alkali in the blood.

62.—It is not yet discovered what is the exact mode of action of the Phosphoric Acid in the organic process, and we must for the present be satisfied with deducing from its constant presence in all the juices and organised tissues of the body, the conclusion that it is indispensable for the vital operations.

In the blood of the herbivora, we find the Alkali in part combined with Carbonic Acid; in that of the carnivora, we find this Carbonic Acid represented and replaced by Phosphoric Acid, without any alteration of the character or functions of the blood.

Ashes of	Human Blood.	Calves' Blood.	Sheeps' Blood.
Phosphoric Acid,............	31·787	20·145	14·806
Alkalis and Alkaline Earths, ...	58·993	66·578	60·576
Carbonic Acid,.....................................	3·783	9·848	19·474

These Analyses show that, as the amount of Phosphoric Acid diminishes, that of Carbonic Acid increases.

These Acids form with the Alkalis found in the blood, compounds of the same chemical character, and Liebig points this fact out as one of the numberless ones which fill, with inexpressible admiration, the soul of the observer of natural arrangements; namely, that an Alkaline Carbonate is identical in it's properties with an Alkaline Phosphate.

63.—It is hence easy to understand that if certain functions belong to the blood which depend on its chemical character, on its Alkaline quality; that for these objects, a change of the Acid combined with the Alkali, the replacement of the Carbonic Acid of the carbonated Alkali by Phosphoric Acid, and *vice versa*, has no influence, because it causes no alteration of the essential properties of the blood.

64.—We can now, with the greatest ease and certainty, determine beforehand, from the known composition of the ashes of the food, the nature and quality of the incombustible constituents of the blood, since we know that those of the blood are derived from the food, and that both are identical.

When the food consists of bread or flesh, which leave in their ashes no Carbonates, but only Phosphates, the blood contains only Phosphates; if we add to the bread or flesh, potatoes or green vegetables, the blood acquires a certain amount of Alkaline Carbonates; if we replace the bread and flesh entirely by fruits, roots, or green vegetables, the blood of man acquires the composition and quality of that of the ox or sheep.

65.—But although the exchange of Phosphoric and Carbonic Acids in the blood, when the diet is changed from animal to vegetable, appears to have no influence on the processes of sanguification, nutrition and production of heat, yet the process of secretion is very

essentially modified in its form, by this exchange. It will not be necessary here, however, to pursue the matter further. The reader who takes any interest in it will find it followed out, in the most beautiful and exact chemical detail, by Liebig, into many branches of physiological science, of the most common and daily occurrence and of universal interest, in the book from which the foregoing imperfect abridgement has been made—his "Letters on Chemistry". Whether it be the true theory of boiling meat, or of bleaching, of vital forces or of making vinegar; of preserving provisions, soup making, putrefaction, crystallization, fermentation, electro-magnetism, decay, digestion or disinfection, or numerous other subjects impossible here to detail, all are explained in a clear, concise manner, on the truest scientific principles, and with a simplicity of language which cannot fail of affording, particularly to the *chemical reader*, the highest gratification.

66.—Before we leave the subject however, let us draw a *resumé* of the foregoing vital operations of the animal organism.

The two principal functions of the animal frame are respiration and nutrition, and man requires in the latter, that is in his food and drink, the means of producing force and heat; he thus creates in his body the resistance which he must oppose to the action of the atmosphere, which daily takes up a part of his organism, the Carbon and Hydrogen of the blood, or, failing that, of the tissues.

67.—When there is a want of this internal resistance, as in starvation, the same natural forces, which determine the vital phenomena, act like a sword, which, gradually but irresistibly, penetrates to the central point of life and puts an end to its activity. Hence the necessity for daily renewal of this resisting power to oppose the natural forces which incessantly strive to annihilate his existence. In every hour a portion of our body dies off, and even in the state of perfect health, the machine after 70 or 80 years becomes the prey of the inorganic powers; all resistance ceases; the elements of the machine return to the atmosphere and to the soil.—"Dust thou art and unto Dust shalt thou return."

68.—At every inspiration a quantity of Oxygen passes to the blood in the lungs and unites with its elements; but although the weight of the Oxygen thus daily entering into the body amounts to 32 or more ounces, yet the weight of the body is not thereby increased, exactly as much Oxygen as is imbibed in inspiration passes off in expiration in the form of Carbonic Acid and Water; so that with every breath the

amount of Carbon and Hydrogen in the body is diminished—but with this exception, all the other substances taken into the body as food, may be obtained in the solid and fluid excrements of man and animals.

69.—Nutritive matters generally divide themselves in their ultimate analysis into Oxygen, Carbon, Hydrogen, Nitrogen, Sulphur, and the incombustible constituents, *viz.*, the Alkalis, Potash and Soda; the Alkaline Earths, Lime and Magnesia, Phosphoric Acid, Peroxide of Iron and Silicic Acid.

70.—The office of these is to supply the body with animal warmth by the combustion of certain parts, Carbon and Hydrogen in the lungs, and by the absorption and assimilation of all into the blood* to keep it supplied with the necessary plastic materials for the formation of the muscular and nervous tissues, the bones, &c. When this has been performed, the materials pass from the body in the form of the excreta†. In the process of digestion those constituents of the food, whether combustible or incombustible, which are soluble in Alkaline or slightly Acid liquids, are dissolved and taken into the circulation. By the action of the Oxygen absorbed in respiration, the combustible portions are ultimately burnt, that is oxidized; the non-nitrogenous or respiratory bodies are converted into Carbonic Acid and Water‡. The plastic substances into Uric Acid, Hippuric Acid and Urea, and their Sulphur, into Sulphuric Acid. By means of the organs of secretion, the kidneys and the intestinal canal, the above-named products of the organic process of combustion and the constituents of the ashes of the food, in so far as they are unfit for further use in the vital operations, are expelled from the organism. The urine contains the soluble, the fœces the insoluble constituents of the ashes of the food.

71.—We obtain daily, in the form of Urea, all the Nitrogen taken in the food both of the young and of the adult; and further in the urine the whole amount of the Alkalis, *soluble* Phosphates and Sulphates, contained in all the various aliments. In the solid excrements are found a number of substances taken in the food which have undergone no alteration in the digestive organs, all indigestible and insoluble matters such as woody fibre, the green coloring matter of leaves, wax, &c.

* The whole weight of the blood in an adult man may be taken as 24 lbs., of which 80 per Cent. is water.

† The solution formed in the digestion of food in the stomach is Acid. The blood is a Saline and Alkaline fluid.

‡ It requires 37oz. of Oxygen, to convert 13$\frac{8}{10}$ of Carbon into Carbonic Acid.

The other elementary substances taken in the food, go chiefly to the formation of substances in the blood, from which the various muscular and nervous tissues, bone, secretions of the body, &c., are supplied.

72.—Intimately connected with this branch of our subject, is the origin and the effect of Malaria on the human frame.

Malaria is generally found to exist upon level coasts, low plains, and deep valleys, and hence altitude may be considered an important consideration with regard to its origin. It also occurs principally, but not entirely, near morasses and stagnant lakes. The Roman Campagna, the plains of Pœstum and Puglia and our own Terai, may be mentioned as instances where, although water is at times abundant, yet at other times the soil is dry.

73.—In like manner it is worst at the dry season, although very deadly sometimes just after the commencement of heavy rains, and it is universally found to be more dangerous in the night than in the day time, so that to go out then, still more to sleep in it, is nearly certain to bring on an attack. In Italy the critical epochs are considered to be when dew is falling—therefore at sunrise and sunset.

74.—The causes to which it is attributed may be considered as three—

1st.—Alterations of temperature from great heat by day to cold and dew at night.

2nd.—The volcanic character of the soil and pestilential gases due to it, as Carbonic Acid and Sulphuretted Hydrogen.

3rd.—The decomposition of animal and vegetable matter which give rise to an unhealthy atmosphere.

75.—The first cause, *viz.*, great alterations of temperature, is a very commonly ascribed one in India, nevertheless Professor Schouw in treating of the Italian Malaria, does not consider this opinion as worthy of acceptance, because there are many regions where the alternations of heat and cold are greater, but where no illness arises, and although he allows that these are considerable on the wide plain of the Campagna, yet he maintains they are still not so great as on the great plain of Lombardy, at Turin, Milan and Bologna, and at Florence in the valley of the Arno, where there is a healthy atmosphere. Again the Malaria exists more on the sea coasts than inland, but it is in the latter situation that the alternate change from heat to cold would be greatest. There are other considerations, however, to be held in mind, such as that the night chill is as much ascribed to exposure to heavy dews, as to mere cold temperature, as the heat also is to much fatigue or exposure to a tropical sun. Other exciting causes exist, however, on

the sea coast, where considerable tracts become marshy and pestilential from the overflowing river waters, when these are unable to find a ready exit to the sea.

76.—Again this cause, when combined with others, may not be without its influence. Supposing a noxious air to be otherwise generated, it might, under the influence of a warm air and the atmospheric motion so created, be kept in circulation or carried about, whereas the reverse might occur under a cold and stagnant air.

Effluvia from drains is more sensibly felt during the cold than during the hot months. Perhaps, however, on the whole, diarrhœa and dysentery are the complaints which are attributed to sudden or night chills rather than fever from miasma.

77.—2nd. *The volcanic character of the soil*—Noisome Gases, no doubt, are generated from soils of a volcanic nature, as Carbonic Acid and Sulphuretted Hydrogen, but numerous instances can be adduced of places highly and even actively volcanic, yet where no Malaria exists, owing, no doubt, te there being no deficiency in ventilation; moreover if it were caused by subterranean emissions, it is not very evident why the illness should be confined to a particular season of the year. If it were these gases also, animals, who are as readily affected by them as man, should also be as subject to the fever, which they are not. On the other hand, as in some degree connected with the subject, it may be mentioned that Humboldt says, at some of the monastic establishments in South America, he found epidemic illnesses attributed to the existence in the neighbourhood of extensive tracts of bare and rocky ground.

At Delhi a very general opinion prevailed that the fever from which that station suffered, was connected with the close neighbourhood of the bare and rocky ridge running immediately behind the cantonment.

78.—The third opinion is, however, the one which is most generally entertained both in Italy and India, *viz.*, that miasma is due to the decomposition of animal and vegetable substances. The Pontine Marshes abound in water; the marshes near Viareggio, the Lentinian morasses, the country round the outlet of the Ombrone and Cesino, the lagunes of the Adriatic Sea, the embouchure of the Po, the Mantuan morasses and the rice fields in the valley of the Po, all offer examples of unhealthy atmosphere. Places of greater elevation, where stagnant waters exist, have likewise the Malaria; as the lakes of Perugia, of Bolsena, and Fucina. And where on the sea coast the

salt and fresh waters mingle and keep up, by the rise and fall of the tides, a constant state of moisture and stagnation, there also a fever-laden air exists.

79.—This view is supported by the fact that in Italy, as in the Terai, the unhealthy atmosphere is connected with the season in which a high temperature favors decomposition. On the other hand the Roman Campagna and the great Puglian plain are dry during the summer; so is great part of the unhealthiest portion of the Terai, which is situated immediately at the foot of the mountains, where the hill streams, having penetrated the superficial, loose, gravelly strata, and flowing below, have not yet risen to the surface. Malaria exists here as much or more than it does further off, where these streams, having burst out in great abundance from the soil, in the shape of springs, have formed considerable tracts into swamps.

80.—M. Schouw explains this in Italy thus " that in these plains (the Roman Campagna, &c.) the noxious vapors do not rise until the pools of water are quite dried up, and the heat comes to act upon the organic bodies which lie at the bottom of them. It is ascertained by experience that noxious air is produced in warm regions by artificially drying up the lakes. That the effects of the Malaria increase after the first rains have fallen is a confirmation of this explanation, since the organic bodies become more liable to decomposition when they are softened by the rain." This explanation is, no doubt, partially applicable to Indian experience. Some believe the sickness to be caused by organic matter diffused through the air in a very minute state of sub-division.

81.—The Italian naturalist, M. Brocchi, endeavoured to obtain some air to analyze from a very unhealthy situation near Rome by condensing it into dew in glasses, artificially cooled down by ice. He obtained two pounds of water in this way, but chemical analysis gave him no extraordinary results.

M. Schouw appears to lean rather to the view that Sulphuretted Hydrogen is an exciting cause, but although this may be the case in the more volcanic soils of Italy, it is more probable to arise, in the Terai, from the existence in superabundance of Carbonic Acid.

82.—In dense forests like the Terai, evaporation goes on slowly from the soil beneath the thickly foliaged trees; the air is moist and cold, and less adapted to circulation than that air, which, lying over tracts destitute of wood, becomes strongly heated, and rising perpendicularly, gives room to currents of other air to supply its place.

The trees also evaporate copiously in a hot climate, and where this is joined to much shade, and even darkness, it is highly probable that larger quantities of Carbonic Acid may be thus evolved than in more open and airy situations with short nights. That there must also be much vegetable matter in the shape of fallen leaves and rotten branches, and decaying grass and rushes of great size, all contributing to this, cannot be doubted. Plants, with a limited atmosphere, are more liable to become diseased—their leaves decay, and by their decomposition they rapidly destroy the Oxygen of the air.

It is a well-known fact in the Terai that the night is more deadly than the day; that a traveller may pass through the forests in the day time without incurring harm (provided he does not rest), but that to pass at night, still more to sleep there, is sure to induce the fever.

83.—It has also been found to accord with experience that whereas a traveller on foot or one in a palankeen will, in all probability, catch the fever, one on horseback, from being more elevated, has a good chance of escape, and one on an elephant will, in all probability, avoid the fever altogether. With this view all dwellings in the Terai, as those of the police, are elevated as much as possible. Some travellers have also asserted that to surround the face with gauze or musquito curtains, and to smoke constantly, is a preservative. It is to be hoped that some of those who may have it in their power will obtain some of the air of the Terai from different elevations, of 1, 9 and 18 feet say, and analyze them by means of the solutions of Potash and of Pyrogallic Acid, or of Hydrate of Potash and Oxide of Copper, and thus by ascertaining the quantities in it of Carbonic Acid and Oxygen, assist in determining a very interesting question.

84.—In Italy it is a widely-diffused opinion that the cultivation of the soil, and the increasing population of the country, afford defensive means against the Malaria, and that it gains the upper hand when agriculture goes to decay, and the population diminishes. This is corroborated by experience in the Rohilcund districts of the Terai, where drainage of swamps, cultivation, and increased population, have diminished the percentage of sickness.

At Viareggio, in Italy, the population before 1733 was only 330, one out of every 15 of whom died annually from the miasmatic pestilence. By erecting sluices, however, to exclude the salt water and let the fresh water flow off, and by other improvements, the health of the place has been essentially improved, and in 1823 Viareggio numbered 4,267 inhabitants.

At Val di Chiana, also, similar success attended the formation of "Colmate," or sluices, which by flooding depressed and swampy tracts with the turbid river waters, eventually silted them up, and by thus raising the general level of the country, forced the river to flow into the sea, without overspreading its banks and causing unwholesome marshes.

85.—Decaying animal matter is by some supposed to be as injurious as vegetable matter, but this is probably a mistake, especially where much moisture or water is not present to aid the formation of the more fetid gases derived from Sulphur, Phosphorus and Hydrogen. If putrifying animal matter were deleterious, sickness would be more rife than it is in the villages of India, and especially the Punjab, in the immediate precincts of all of which a large heap of such material, consisting of the deceased village cattle, is to be found. Still more would it be so in military camps which, if standing for any length of time, become surrounded with a cordon of similar disagreeable matter. But experience has not found this to be the case, nor would the natives be so indifferent to this as they are, if it were found decidedly to produce sickness; lastly, in dissecting rooms, tanneries, and other places where animal effluvia prevail, no ill effects result.

86.—In many stations in India sickness has been attributed to *green* vegetation, and orders have been issued to destroy, by cutting down the annual rank vegetation which springs up chiefly with the rains, and to trim all trees of what has been considered too luxuriant growth. This opinion is apparently founded in error, at least as long as the circulation of air is not decidedly interfered with. It is known that plants evolve more Oxygen than they consume. Absorbing the Carbonic Acid of the air, they appropriate the Carbon and give out the Oxygen, and at night only, when deprived of light, heat, and probably electricity, do they absorb the vital principle, Oxygen, and give out the deleterious Carbonic Acid.

The same vegetation, however, cut down, would, if left to decay, produce a very different effect. The drying vegetable tissue contains probably as much as 45 per cent. of Carbon, and 2 per cent. Nitrogen, both sources of evil.

87.—A traveller in Ceylon (Mr. Sullivan) mentions in his rambles, that the tanks, although covered with vegetation, are wholesome, but that the rivers are unhealthy. He explains this by saying that the plants on the former assist in absorbing Carbonic Acid; and the smaller duckweed, &c., appears to attract the insects, so as to leave other parts free and pure for drinking purposes.

The rivers, on the other hand, are unwholesome, because they carry down much vegetation, which, on their subsidence, is left to decay. Their beds also not being rocky but sandy, the waters do not sweep away the vegetable matter in suspension, but sinking themselves into the soil, leave it on the banks to decay.

88.—This is a subject which has baffled residents in India for many years, and is even now but little advanced beyond conjecture; nor is it likely that we shall ever arrive at any positive results, unless aided by actual chemical and microscopic analysis.

89.—Dysentery, which it has just been said is frequently attributed to sudden or great atmospheric changes between the day and the night, is also attributed and more frequently to brackish water and salt provisions.

On this subject it may be well worth while to notice and describe the very singular circumstances of what Liebig calls the "endosmosis" of salt in the system.

90.—If we tie over one opening of a glass tube, 4 to 6 inches long and about $\frac{1}{4}$ of an inch wide, with a moist membrane (intestine or bladder, &c.,) and fill it to $\frac{1}{2}$ with spring water, and then place it in a glass of the same water, so that the water within and without the tube stands at the same level, we observe, even after hours or days, no change in the level of the two liquids. But if we now add to the water in the tube closed with bladder a few grains of common salt, we shall see after a few minutes the water in the tube rise above the level of that in the glass; it moves upwards.

91.—If we now add salt also to the water in the glass, and in such quantity that the proportion of salt in the two liquids is the same, no change of level occurs. But if more salt, in proportion, be added to the water in the glass, than to that in the tube, the opposite change takes place;—the water in the tube sinks, that in the glass rises.

92.—We see from this that the spring water flows towards the saline water, and the weaker solution of salt towards the stronger; as if forced by an external pressure to pass through the pores of the membrane in opposition to the laws of gravitation. By the mere addition of common salt to the water, the tube with the bladder acquires the property of a pump, and sucks up water with a force which, in many cases, is equal to the pressure of a column of mercury, two to three inches in height.

93.—The same result is obtained with ox blood deprived of its fibrine, and placed in a glass of warm water; the water flows towards the blood; and that this is in a great measure due to the salts in the blood, is shown

by the same results occurring with the liquid obtained by pressure from blood coagulated by heat, and which contains common salt and other salts.

94.—If a free Alkali, in the form of Carbonate or Phosphate, be added to the salt solution, the suction power is increased, and if the liquid in the glass be slightly Acid, while that in the tube is Alkaline; the flow takes place with the most velocity.

95.—Thus, he observes, in the animal body are united all the conditions for rendering the circulating system, by means of the blood, a most perfect suction pump, which performs its duties without stop-cocks or valves, without mechanical pressure, nay without regular canals or passages for the transmission of the fluids. The solution formed in the digestion of food in the stomach is Acid, the blood is a saline or Alkaline fluid. The whole digestive or intestinal canal is surrounded by a system of infinitely ramified blood-vessels in which the blood moves with great velocity. By means of the urinary apparatus, the water which has flowed into the blood is immediately filtered off, and the circulating fluid is thus always kept in the same state of concentration.

96.—We can now easily understand the effects produced on the organism by waters containing different proportions of salt.

If we drink pure spring water, it is rapidly passed through the system by the kidneys. If we drink water containing about as much salt as the blood contains (from ·75 to 1·0 per cent.) no unusual evacuation occurs. It is hardly possible to drink more than three glasses of such water, a sensation of repletion, pressure, and weight at stomach, indicate that water, having a percentage of salt equal to that of the blood, requires a far longer time for its absorption into the circulation.

97.—Lastly, if we take a solution of salt, the percentage of salt in which is somewhat higher than in the blood, there occurs the opposite of absorption, namely purging.

From the foregoing we perceive the evil effects likely to result from the use of salt or brackish waters, and may also deduce reasons for the benefits derived from persons suffering from disease so contracted, from a sea trip, or even a residence at the sea side, and inhaling the salt breezes.

SECTION III.

ENGINEERING.

1.—LET us now touch on a few matters of interest to the Engineer, in that point of view which it has been the object of these pages to consider, namely, the Chemical.

None can be more so than Iron. If India could make her own Iron her progress as a productive nation would, beyond all doubt, be marvellous, and as the time is not far distant, it is hoped, when every Engineer will have to judge of the quality of the Iron of his own district, the chemical rationale of its manufacture will not be altogether without interest.

2.—Iron exists in nature principally as the Sesquioxide or Peroxide, which is the important constituent of most of our ores; it is also found as Protoxide, Silicate, Carbonate, &c. With the Oxide of Iron, contained in the ore, are always found a great number of impurities in chemical and mechanical admixture, so much so that the usual produce of Iron is not above 30 or 40 per cent. of the weight of ore. These extraneous substances may be generally represented by the following:

Oxide of Manganese, Oxide of Chromium, Silica (Oxide of Silicon), Alumina (Oxide of Aluminum,) Phosphorus (or Phosphoric Acid), Sulphur (or Sulphuric Acid), and Carbonates.

These substances all exist as Oxides, forming bases and acids which have entered into combination with one another. The object of the manufacturer is to get rid of all these substances, but more especially to reduce the Oxide of Iron to pure Iron.

3.—For this purpose the Blast Furnace is used, where the ore is exposed to a high temperature, in order to facilitate chemical action, and a substance, having a greater affinity for Oxygen than Iron has, is presented to it. This is usually effected by the Carbon of common Coal, which enters into combination with the Oxygen of the whole mass, and is carried off as a volatile Gas (Carbonic Oxide or Carbonic Acid), leaving in the furnace the reduced metals and metalloids,

Iron mixed with { Manganese, Chromium, Silicon, Aluminum, Phosphorus, Sulphur. }

4.—It is found, however, that the presence of Carbon alone will not completely reduce the metals, and that it is necessary to introduce a

"flux," which is *Limestone*. This *Limestone* contains *Silicate and Carbonate of Lime*. By the action of the heat, the Carbonic Acid is driven off, leaving a portion of free Lime mixed with Silicate of Lime. The action of this is highly important in the process of reducing. Its action is first mechanical, and then chemical. *Mechanical*, because Iron and Oxide of Iron are highly infusible, but a Silicate of Lime is much more easily fused; the latter therefore acts as a flux. It also, by encircling the iron as it becomes reduced, defends it, by exclusion of the air, from the tendency to re-oxidize. *Chemical*, because the free Silica introduced with the Lime enters into combination with the unreduced portions of the Oxides of the extraneous metals, while the Lime takes up any of the Phosphoric or Sulphuric Acids that may also not have been reduced by the action of the Carbon of the Coal. In short, the Lime forms a slag or glass with the impurities of the Ore, while the Coal reduces the Oxide of Iron to its metallic state.

5.—The whole melted mass descending in this state to the bottom of the furnace, is there drawn off at different levels, owing to the difference of specific gravity of the Iron (the heavier portion) from the other substances or slag. The Cast Iron thus obtained in the *Pig*, is however far from pure. It is a Carbide of Iron, containing from 2 to 5 or 6 per cent of *Carbon* in chemical combination, and often some portion in mechanical admixture, together with traces of all the other impurities contained in the original ore, and those introduced with the Limestone and Coal. Almost all Pig Iron that has been analyzed, has been found to contain the following substances:

Manganese, Chromium, Silicon, Aluminum, Phosphorus, Sulphur, and Carbon in large quantities.

6.—The Carbon enters into chemical combination with the Iron, giving it its peculiar crystalline appearance, pure Iron being a ductile uncrystalline substance. Sulphur, Phosphorus, and probably Silica also, enter into chemical combination, forming Sulphide, Phosphide and Silicate of Iron. These are infinitely more injurious to the tenacity of the Iron even than the Carbon; Sulphide and Phosphide of Iron being extremely brittle substances, whereas Carbide, though not nearly so strong as pure Iron, is, nevertheless, when not too highly impregnated, a very strong substance; and in some cases, where hardness and inflexibility alone are required, is superior to pure Iron.

7.—Manganese and other pure metals are probably only in mechanical admixture, but even in that state they interfere with the tenacity of the Iron, by cutting off the connexion of its particles. *Pig Iron* is

usually, previous to being run into important castings, re-melted in a cupola or air-furnace, which again further separates it from some of its impurities, and by the action of a current of air, oxidizes again a portion of the Carbon, which passes off as Carbonic Acid Gas, leaving the Iron still purer.

8.—The next process through which Iron passes before being reduced to the malleable state (and which, although not general, is made use of by some manufacturers,) is that called "*Refining*," being re-melted, and while in the liquid state lying in thin layers on a flat hearth, a strong current of air is blown upon it, when by oxidation, a large quantity of the Carbon is removed, and it is consequently so much the more quickly reduced by the "*puddling*." This is however not at all necessary, as the result is obtained, though not so quickly, by "*puddling*" only, and it is simply a question of convenience and expense, upon which practical men do not appear to have agreed.

9.—In "puddling," the refined or *Pig Iron* is placed in an oven, from which the atmospheric air is excluded as much as possible, and being covered with a certain quantity of iron scales and rust, collected from the smiths' forges, the rollers and the other parts of the works, and the slag pressed from the puddled iron in previous processes, together with some Limestone, a powerful flame is blown down upon the whole mass, until it is reduced to a liquid state: it is then stirred about for some time with a bar introduced through a small aperture, and with the same temperature kept up, the Iron at last becomes solid, and collects in large spungy balls in the liquid *slag*.

10—These puddle balls are now withdrawn and placed under a heavy hammer, or press, when the liquid slag contained in the pores runs out in large quantities: It is then, while hot, passed through 3 or 4 grooves of rollers, termed "puddlers' roughing rollers," and also through 3 or 4 grooves, termed "puddlers' finishing rollers," each of which reduces it in size.

11.—It is now termed No. 1, or puddle-bar-wrought iron.

The Iron obtained after this process must evidently have undergone some very important chemical change from the great difference in its physical character; it is no longer crystalline or brittle, it is tough, malleable and fibrous, and cannot again be re-melted at the same temperature as before; it also exhibits various other distinctive properties well known. The Pig Iron when placed in the puddling furnace, is a Carbide of Iron, containing various other impurities before enumerated, and the object of the manufacturer must be to get rid of all extraneous

matter, and obtain the Iron in as high a state of purity as possible: this though a very complex chemical change, is performed with considerable success in the manner described. The following re-actions represent the changes which take place:

12.—The impurities to be got rid of are usually

Carbon.	Silicon.
Magnesia.	Aluminum.
Chromium.	Phosphorus.

Sulphur.

For this purpose the Pig Iron is "boiled" in a fused mass containing Sesquioxide and Protoxide of Iron, (which are the component parts of the rust and scales introduced,) and Lime and Silica (from the Limestone.)

The following is an Analysis of the Iron cinder or slag pressed from the Iron after coming from the puddling furnace, and which is usually put into the furnace again with the Pigs.

Silica,	14·0
Oxygen, 17·5; Iron, ... 58·0; —— 75·5 } Sesquioxide and Protoxide of Iron,	75·5
Protoxide of Manganese,	2·0
Alumina,	2·5
Phosphoric Acid,	3·5
Lime,	0·75
Chlorides of Potash and Magnesia,	1·0
With traces of Copper, Molybdena, Tungsten and Vanadium,	0·75
	100·00

The above is not very different in its general composition from the usual slag or "refining cinder" formed by exposing fused cast Iron to the action of the blast, but the presence of 3 metals rarely met with, particularly the last, hitherto found only in one Swedish mine, render it an alloy of great interest.*

* This piece of slag was from Mr. Thornicroft's iron works near Wolverhampton. It runs in a liquid state out of the Iron, when put into the press at a white heat from the puddling furnace, and is used again as a flux in reducing the Pig Iron to a Malleable Iron.

13.—The Oxide of Iron at this temperature gives up its Oxygen to all those substances for which it has a greater affinity, forming with the Carbon, Carbonic Acid, which passes off through the chimney of the furnace, with the Sulphur, Sulphurous Acid, which is also evolved, and with all the other metals their Oxides, which respectively form Acids or Bases. These have a stronger affinity for Lime and Silica than they have for Iron, and consequently separate from the Iron, combining with one or the other. The resulting compounds being fusible at *a lower temperature* than *pure Iron*, remain liquid, while the Iron becomes solid, and they are mechanically separated from it by being pressed out, as water from a spunge, under the press and rollers.

The phenomenon of the Iron becoming solid at the same temperature at which it was before liquid, is easily accounted for by the fact, that pure Iron cannot be fused at the same time temperature as Carbide of Iron, and consequently as soon as the Carbon is driven off, it must become solid.

14.—In puddling, the workman knows as soon as the operation is complete by the mass "settling," that is, the surface ceasing to boil and bubble, and the Iron as it becomes solid, interfering with the free movement of the stirring bar through the mass. The cause of this bubbling is the escape of Carbonic Acid, and as soon as that ceases, it indicates that all the Carbon has disappeared.

15.—These theoretical reactions are borne out by the facts of analysis, which prove that the Iron in its passage from the cast to the malleable state, has actually experienced the change here represented, malleable Iron not being found to contain those extraneous matters which cast Iron does, or at least in very small quantities, the greatest amount of Carbon usually found being from a $\frac{1}{4}$ to $\frac{1}{2}$ per Cent., and its quality is exactly regulated by its purity.

16.—The process of rolling has a much more important influence than might at first sight appear evident, on the quality of the Iron, *viz.*, in removing that portion of the slag which it retains after the first crushing. As the Iron becomes reduced in temperature, a certain portion of this slag solidifies and is retained, but at each re-heating, it is again liquified and pressed out. So long as any slag can be pressed out from the Iron, the rolling should be continued. In each portion of this process not only is the most careful manipulation necessary, but it is indispensible that the proportions of all the different substances which supply the materials for chemical reaction, should be strictly attended to; The Coal must be of a certain quality, according to the quality of the

ore it has to reduce; the Limestone must contain different ingredients and in different proportions, according to the number and proportions of the impurities it has to extract, otherwise the result must be great waste, or a bad quality of Iron.

17.—Although this process is that generally adopted, and generally found successful, it is by no means always so; in fact in many cases it has failed to produce Iron at all fit for use, and in a great many cases has produced very inferior qualities. In many cases Iron ores are found which contain impurities different from those here enumerated, and which cannot be removed by the ordinary constituents of Limestone and Coal, and it is a fact, that *even at this day* mines rich in Iron ore are abandoned, because the most experienced practical men have failed to reduce the Iron by the ordinary operation; and even under the most favorable circumstances, every attempt has as yet failed to produce perfectly pure Iron.

18.—The manufacture of Charcoal and Coke are also subjects interesting to the Engineer.

Wood Charcoal.—($C_{36}H_{22}O_{22}$.)—Wood consists of Carbon, Hydrogen and Oxygen, the two latter being in the proportion to form water. When heated in the open air, it burns completely away, with the exception of a small quantity of white ash. But if a slip of wood be lit, and as it burns introduced slowly into a glass tube closed at the bottom, so that the flame may continue to burn at the mouth of the tube, it will be found that a long strip of black Charcoal is left behind. In this case the supply of air is limited, and only the more volatile ingredients burn away. This experiment illustrates the process of Charcoal burning, which is as follows:

19.—A number of billets of wood are built up vertically in two or three rows into a large conical heap, which is covered over with turf or moistened Charcoal ash, holes being left at the bottom for the air to get in. A hollow space is left in the middle of the heap, to serve as a flue for the gaseous matters which are evolved. The heap is set on fire by throwing burning pieces of wood into the central opening, near the top of which, however, a kind of grate, made of billets of wood, is placed, to prevent the burning fuel from falling at once to the bottom.

20.—The combustion then proceeds gradually from the top to the bottom, and from the centre to the outside of the heap; and as the central portions burn away, fresh wood is continually thrown in at the top, so as to keep the heap quite full. The appearance of the smoke shows how the combustion is proceeding; when it is going on properly

the smoke is thick and white; if it becomes thin, and especially if a blue flame appears, it is a sign that the wood is burning away too fast, and the combustion must then be checked, by partially stopping up the holes at the bottom, or by heaping fresh ashes on the top and sides, and pressing them down well, so as to diminish the draught.

21.—As soon as the combustion is completed, the heap is completely covered with turf or ashes, and left to cool for two or three days. It is then taken to pieces, and the portions still hot are cooled by throwing water or sand upon them. The quantity of Charcoal thus obtained, varies with the manner in which the combustion is conducted, 100 parts of wood yield on the average from 61 to 65 parts by measure or 27 parts by weight of Charcoal. When the burning is very carefully conducted, the quantity may amount to 70 per cent. by measure. When burned, Charcoal leaves about 1 to 2 per cent. of ash. It has very great absorptive powers, as has been elsewhere mentioned, one cubic inch (having about 100 superficial inches of surface) will absorb and condense 90 cubic inches of Ammoniacal Gas; of Sulphuretted Hydrogen 55; 35 of Carbonic Acid; 9·25 of Oxygen; 7·5 of Nitrogen and 1·75 of Hydrogen.

22.—In England a large quantity of Charcoal is obtained in the dry distillation of wood for the preparation of Acetic Acid. For this purpose the wood is heated to redness in cast iron cylinders, whereupon a number of volatile products are given off, including a large quantity of tarry matter, an inflammable spirit called Wood Spirit or Wood Naptha, and Acetic Acid, and in the retorts there remains a quantity of Charcoal.

23.—Ordinary bituminous Coal, which consists of the remains of ancient forests and peat mosses, and appears to have been formed from wood by a process of slow decay going on without access of air, differs from wood in containing a larger proportion of Carbon and less Oxygen and Hydrogen, it also contains Nitrogen derived from the tissue of plants. This substance when heated in the open air burns away like wood, leaving nothing but a white ash, but when strongly heated in cast iron cylinders with exclusion of air it undergoes a decomposition like that which takes place in wood under similar circumstances, a large quantity of Volatile products being given off, as Carburetted Hydrogen Gas (the Gas used for illumination) and a tarry liquid, containing Ammonia and a variety of other products; while a black, dull-looking, porous mass, called Coke, is left in the retorts.

24.—This substance consists mainly of Carbon mixed with a quantity of inorganic constituents, greater than that which occurs in Wood Charcoal so that it leaves a larger amount of ash when burned. The aspect of Coke varies much according to the kind of Coal from which it is obtained; bituminous Coals, such as the Newcastle Coal, undergo a kind of semifusion before they decompose, and yield a very porous Coke, having a brilliant metallic aspect; Anthracite, on the contrary, undergoes but little alteration by heating, and yields a Coke having very much of the form and aspect of the original mass.

25.—Coke is the fuel used in the Iron districts of Wales and South Staffordshire for reducing the metal from the ore. It is there prepared from the Coal which occurs in the same districts, by partially burning that substance in longitudinal heaps, more or less covered up with the ashes of former fires, the object being to produce a smothered combustion similar to that described as used for the preparation of Wood Charcoal. This process is very wasteful unless carefully conducted.

26.—*Coal.*—It seems strange, considering the vast importance of the subject, that no accurate method of ascertaining the true value of Coal as a fuel has yet been discovered. Several modes have been recommended in various books on the subject; but the results show that there is not one plan which can be fully depended on.

27.—The chief constituents of Coal are Carbon, Oxygen and Hydrogen; but it also contains appreciable quantities of Sulphur and Nitrogen, and a certain proportion of Ash.

An Analysis of one of the best Welsh Coals is as follows:—

Carbon,	90·1
Hydrogen,	4·3
Oxygen,	2·4
Nitrogen,	1·2
Sulphur,	0·5
Ash,	1·5
	100

The specific gravity of such a Coal is 1·3

28.—It is by no means an easy matter to tell the quality of Coal by its appearance; we may, however, conclude that when it is black and shining, and has a conchoidal fracture, it is rich in Carbon, as Anthracite; if it is of a brown colour, and of a soft velvety structure, it is generally deficient in that element, though probably rich in Hydrogen.

29.—Coals are always distinctly stratified, and have a cleavage generally at right angles to the plane of deposition—the different laminæ of which they are composed are generally in close contact with one another; but thin layers of other minerals, such as Iron Pyrites, Carbonate and Sulphate of Lime, Galena, Sulphate of Baryta, and the Soda Salts sometimes occur between the laminæ.

Coal occurs in seams of from two inches to 43 feet in thickness.

30.—The upper and lower parts of the seam are generally of an inferior quality; the lower part, which is called Shale, owes its inferiority to its being mixed with many of the mineral substances which, in ages past, formed the soil in which the plants of which Coal is composed had root and flourished.

The inferiority of the upper part of the seam is usually owing to the infiltration of water depositing, in the pores of the Coal, earthy particles from the overlying strata.

31.—It will be sufficient for present purposes, if we can ascertain in any specimens of Coal that may come before us, the quantity and quality of *Coke*, and the quantity of *Ash*, and this can be effected in the following manner:

32.—*Estimation of Coke*—Take a piece of Coal, weighing say one seer, and place it in a thick earthen vessel or ghurrah, in which a hole about half an inch in diameter has been made. This hole should be at first stopped up with a plugget of Clay; stop also the mouth of the vessel with Clay; a piece of metallic piping about half an inch in diameter, must be inserted through the Clay into the vessel; fix on to the outward end of the piping a piece of India rubber tubing, and place the end of the latter under water. Put the ghurrah on a very brisk fire: after 10 minutes, or after keeping up the heat till no more gas escapes from the end of the tubing, remove the latter, and close it, or close the hole in the ghurrah, temporarily with a fresh plugget of Clay. Allow the vessel now to cool, break open the Clay top, and the residue will be the Coke. This should be weighed and the percentage ascertained. On cooling, *good* Coke splits into long prismatic masses, in some degree resembling basaltic columns. Its colour is a steel grey, almost approaching to Silvery whiteness. If there is an irridescence over the Coke it shows the presence of much Sulphur, which by no means improves its value.

The percentage of Coke varies from 35 to 92, and some Coal contains so much earthy matter that it will not Coke at all.

33.—To estimate the *Ash*.

Pound a seer of Coal in a mortar, then place it over a hot fire in an open earthen vessel, and allow it to burn protected from the wind, till no flame or smoke remains, it is then weighed.

The percentage of *Ash* varies from 1 to 21.

34.—The composition of the ash of a Coal varies according to the nature of the rock in the vicinity of the seam, from which it is extracted; the following is an Analysis of the ash of the Welsh Coal mentioned above.

Silica,	34·2
Alumina and Oxide of Iron,	54·1
Lime,	6·2
Magnesia,	0·6
Sulphuric Acid,	4·1
Phosphoric Acid,	·8
	100

Nearly all Coals bear the names of the places at which they are mined, but the several varieties may conveniently be classed under four heads *viz:*

Cubical Coal.	Slate Coal.
Cannel Coal.	Glance Coal.

and it is no difficult matter at once to determine to which of the abovementioned varieties any particular specimen belongs

36.—*Cubical Coal* is black and shining; easily broken; it occurs in Cubical masses. If when ignited it becomes soft and "puffy" it is valuable as a smithy or forge Coal, but does not do well for a grate, as it is apt to clog the bars.

Specific Gravity, ... 1·2

37.—*Slate Coal* is dull black, difficult to break, and separates in sharp-edged masses. It usually contains a high percentage of ash, but is a valuable Coal for open fire places.

Specific Gravity, ... 1·3

38.—*Cannel Coal* (a corruption of Candle Coal.) Its colour is a velvety black, with a resinous lustre; it burns very readily; and does not soil the fingers. It is the best Coal for Gas making, and is in consequence the most valuable Coal known; its price being as high as 30 shillings a ton, while ordinary Coal is not more than 8 shillings at the pit's mouth.

Specific Gravity, ... 1·4

39.—*Glance Coal*, colour blue black with metallic lustre. It burns without flame and is nearly pure Carbon. Anthracite is a species of Glance Coal.

Specific Gravity, ... 1·5

40.—*Stone.*—In the selection of his materials for building purposes, it is evident that even a limited acquaintance with the simpler methods of Analysis, and a knowledge of Geological Chemistry must be of great use to the Engineer. He will be able more exactly to appreciate the value of his Granites (knowing that even they may decompose), his Trap Rocks, Sandstones, Limestones and Magnesian Limestones, while he will be able to determine absolutely, the purity of the Sand, Clay, or Lime which he uses in every work.

The worth of a Limestone for burning, or of a Clay for embanking, or of a Sand for mortar and other purposes, may be determined with certainty and without much difficulty.

From his chemical knowledge he will also be able to understand with more accuracy, the causes of the setting and hardening of mortar and Hydraulic cements, as well as the nature of the deteriorating causes, which tend to destroy in certain situations the stones, the bricks, and the mortar of his structures.

41.—If analyzing a Limestone for the ingredients usually found, he will separate his clay and sand together, by dissolving in Acid. Then obtain the separation of these two, either roughly, by affusion and subsidence with water, or more accurately by fusion with Alkalis, filtration for the Silica, and precipitation by Ammonia for the Alumina. From the first solution he will obtain his Iron by the aid of Ammonia, his Lime by the use of Oxalate of Ammonia, and finally, his Magnesia by Phosphate of Soda. The details of these processes have already been given.

42.—Quick-lime is Limestone or Carbonate of Lime from which the Carbonic Acid has been expelled by burning. When exposed to the air, Quick-lime very soon absorbs water, the lumps crumbling to a bulky powder, which is Hydrate of Lime or slaked Lime; the same effect is produced by the usual practice of sprinkling with water. Fat Limes (containing much Lime) burst and break under the influence of water with considerable violence. Poor Limes do so more slowly. Under this process sufficient heat is evolved to inflame gunpowder. Limestones, particularly Magnesian Limestones, must not be burnt with too great a heat, or the contained Silica will fuse into a glass. The hardening of

Mortar is chiefly owing to its reconversion into the Carbonates by imbibing Carbonic Acid, but other changes also take place with the Silica and Alumina contained in it, the former producing a Silicate of Lime, and having a useful mechanical effect in preventing the shrinking of the Mortar, and presenting nuclei round which the Lime adheres.

43.—Hydraulic Limes are usually prepared from mixtures of Carbonate of Lime with Silica, or Silicate of Alumina or of Magnesia. When a Limestone of this description is calcined, a double Silicate of Alumina (or Magnesia) and Lime is formed, which is capable of combining with water to produce a compact Hydrate, which resists the action of that solvent. In order that a Limestone, containing Silica, may be employed for the production of Hydraulic Lime, it is necessary that this ingredient be present in a state in which it is capable of entering readily into combination with the Lime, which is the case with the Silica contained in Clay, which is, in fact, a Silicate of Alumina. If Carbonate of Lime be mixed with gelatinous Silica, a good cement is obtained on calcination, but if sand or rock crystal be employed, the resulting product is valueless. If Acid be not at hand, a Limestone may be recognized by being held in the apex of the blue flame of the spirit lamp under the blowpipe, when, after being causticized, it colors the flame carmine red (the characteristic color of Lime as before mentioned) but much weaker than a Strontia Salt.

44.—The various changes Lime, Clay, and Sand, undergo chemically, in their combinations—whether agriculturally or architecturally speaking, will, if they can be appreciated in this light by the engineer or the land proprietor, no doubt form a source of great and novel interest. They are as yet but imperfectly understood even by the learned.

Among the effects arising from some of these combinations, is the decay of plaster and of bricks in certain situations, and the efflorescence or nitrification on walls. By the mixture of Milk of Lime (Hydrate of Lime and Water) with imperfectly calcined clay, a decomposition is effected, and the Alkalis, Potash and Soda, existing in the soil and mixed up with the bricks or the mortar, are set free and at liberty to combine with Nitric or Sulphuric Acid if presented to them, forming Nitrates and Sulphates, as Nitrate of Potash, (Saltpetre). Nitrate of Lime is in like manner formed from the plaster or mortar, and being a very deliquescent Salt, causes the decay of the latter. Ammonia (NH_4O) and Carbonic Acid, are the constant products of air, of rain water and of decaying organic matters; from the latter also Sulphuretted Hydrogen ($H\ S$) is a no less common production. Hence we see the source of the Nitrates, Carbonates and Sulphates, which are so universally found.

45.—These efflorescences are sometimes more visible at the junction of the brick with its mortar, as might be expected from the influence on the Clay which the Milk of Lime has been said to possess. Plastered walls are very generally observed to retain their firmness for a height of two or three feet from the surface of the ground; above this height, the plaster decays, falls off, and leaves the bricks exposed. During the night, where there is much vegetation, there must be an unusual amount of Carbonic Acid exhaled, and of Ammonia there is always plenty from the drains and the decaying matter therein. The specific gravity of the former is 1·5, while that of Nitrogen is only ·97, and of Ammonia ·59, hence in all probability the formation below or near the surface of the insoluble Carbonate of Lime, while above the deliquescent Nitrate of Lime is produced, which washes and falls off from day to day with the plaster from whence it originates. If Potash be present in the mortar, the Nitrate of Lime is decomposed, aided by the superior crystallizing power of Nitre, and Saltpetre is formed. The moisture on newly plastered walls is due to the formation of the Carbonate of Lime going on in the mortar; this expels the water which appears on the surface.

46.—In the selection and cutting of Timber, an observation of natural laws will serve to guide the Engineer. Nature lays up a store of sap for the first nutriment of the leaves in spring. If therefore trees have their bark stripped off in the spring, and are cut in the autumn or winter following, the circulation not having been renewed, they will be found most firm and free from sap, and less liable to undergo decay from the action of moisture and air. As a general rule, the woods which afford most charcoal and earthy matter, and the least proportion of gaseous elements, are the most durable.

47.—In Irrigation it should be remembered, that not only does water act as a liquid manure on a large scale, that is, that being a solvent of organic, saline and mineral matters, it conveys these to the roots of the vegetation to which it is supplied, but also that it is in a still greater measure due to the oxygen of the air it contains, that decomposition of the ingredients of the soil is effected, and nourishment supplied to the crop. River water being the purest next to actual rain water which we have, contains in proportion, but little of saline ingredients, "but," Liebeg says, "the advantage of irrigation consists chiefly in supplying Oxygen

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NOTE.—Much that is useful on these points is contained in the Manual of Civil Engineering and Architecture, lately published by Colonel Goodwyn, of the Engineers.

to the roots of plants." Indeed if it were not so, marshes should be the most productive lands. "The quantity of water necessary for this purpose is very small, so that it is sufficient to cover the meadow with a very thin layer, if this be frequently renewed."

Sir H. Davy says,—"In general those waters which breed the best fish are the best fitted for watering meadows; but most of the benefits of irrigation may be derived from any kind of water. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilizing effects when applied to a calcareous soil, are injurious on soils that do not effervesce with Acids, and that calcareous waters, which are known by the earthy deposit they afford when boiled, are of most use on silicious soils, or other soils containing a remarkable quantity of Carbonate of Lime." Spring waters are often highly nourishing to grasses, and especially when they are thrown out by marly beds.

48.—In the foregoing and in many other points, such, for instance, as the manufacture of Gas and such as involve the use of electric agency, whether for Telegraph purposes or for exploding gunpowder, for lighting or producing colors, a little acquaintance with the "chemistry of common life" will be found to be of the greatest benefit to the Engineer. The importance, the necessity of it, is being every day more acknowledged at home, and not one but numerous volumes on it are constantly issuing from the press. Among these perhaps none would be found more practically useful in India than "Plattna and Muspratt on the use of the Blowpipe." With this instrument, (the blowpipe), which is so portable, much may be done, and where laboratory apparatus and chemicals are neither very plentiful nor very pure, as in many parts of India must necessarily be the case, it becomes of much importance.

SECTION IV.

GENERAL—*Photography.*

1.—With reference to the application of Chemistry to general subjects, I will not detain the reader further than by offering a few remarks on Photography; which is an art now much practised in England by Amateurs, and one likely to afford abundant and interesting occupation also in India.

2.—Without some knowledge of Chemistry, it is impossible to understand the mode of operating and the rationale of Photography. In the very first steps taken in this fascinating science, the student is at once plunged into chemical nomenclature, chemical combinations and chemical manipulation, and he very soon becomes familiar with a numerous catalogue of Salts, with the effect of light on them, and with their effects on each other.

3.—There are many things in the Theory of Photography even yet so little known and explained as to justify the assertion that the art is still in its infancy, and the practice of it in new climates, where greater light, heat, dust, &c. prevail, must be expected to be attended with new difficulties. Nevertheless, there is no reason, I believe, why Amateurs in India, who have time to devote to it, should not be as successful as so many are in England in producing good and valuable pictures of the numerous objects of interest with which they are surrounded.

4.—The manipulation on metal plates (Daguerrotyping) is so intricate, that it has been greatly deserted of late years for the more simple Collodion Process, and it is this which, from some experience, I would venture to recommend to the amateur. It possesses many advantages. The apparatus and mode of operation are both much simpler. The impression produced, not having the glare of a Daguerrotype, is more easy and pleasant to look at, bearing considerable resemblance to a mezzotint engraving. The portrait, if it be one, may be viewed from either side of the glass, consequently it can be seen as in nature, and not reversed like a Daguerrotype; if properly managed, the results are quite equal in delicacy and truth to the other process; it is far more rapid in working, requiring from 3 to 20 seconds where the other requires 2 or 3 minutes, and finally, being on glass, any number of positives may be printed off from a negative, once obtained.

5.—These are great advantages, but there are also some disadvantages, the first of which is the tendency of Collodion to spoil by keeping. Fortunately it is not difficult to make of tolerable quality, so that this, even in the wilds of India, is no insuperable bar. Collodion is simply Gun Cotton dissolved in Ether. Its preparation may be seen described in Hunt on Photography, or De la Motte, or others of the many books on the subject. If properly made the cotton should dissolve entirely in Ether with the aid of very little Alcohol, but the amateur can scarcely expect to accomplish this. Were he in London he would probably send to "Thomas," or "Bland and Long," or elsewhere, and purchase it at once, of far better quality and cheaper than he himself could make it, but being in India, it is highly probable that he must endeavor to make it himself or go without. Fortunately, as I have said, it is no very difficult task to produce a tolerably good Gun Cotton, and one that will dissolve in Ether entirely or nearly so, with the aid of no more Alcohol than is allowed in the "Manuals" on the subject.

6.—Gun Cotton is prepared with the aid of Saltpetre and Sulphuric Acid (*vide* Hunt). Soaked in the mixture and well impregnated with it for 2½ minutes, and then thoroughly washed and dried, it dissolves when shaken up in good Ether, with the aid of about ¼ of its bulk of Alcohol, and being then iodized with a prepared iodizing solution, is used as the sensitive film spread on glass plates to procure Photographic impressions.

7.—It is of importance that the Ether should be good, yet not too strong, and it may be purified by shaking it up with some distilled water, from which it can afterwards be withdrawn as it floats on the top, owing to its less specific gravity, by Syphon.

8.—On the addition of the iodizing solution, the previously colorless liquid rapidly assumes a rich amber tint, and is then fit to use, that is to be poured on to a clean glass plate, where, the Ether immediately evaporating, a beautifully delicate film of the Cotton is left behind.

9.—After being floated on to the glass plate, its subsequent treatment in the Nitrate of Silver bath, and in the Camera; development with Pyrogallic Acid or Protosulphate of Iron, and fixing with Hyposulphate of Soda, may be learned from the books, and are simple enough. Let the operator be careful only, especially if his Collodion be very sensitive, that his room is *quite* darkened from all *daylight*, having a candle only to see by.

10.—The troubles of the amateur in India will probably consist in obtaining good and pure Sulphuric Acid, Ether and Alcohol; he may have to make his own Iodide of Silver, (which is done from the Nitrate)

and iodizing solution. His Glass baths will be broken when "marching" &c. and they are not to be replaced here; he will have therefore perhaps to use Porcelain baths, which are not so convenient. If his apparatus be not simple and clean, he will constantly be fouling his Nitrate of Silver bath, which blackens everything it touches; he will have constantly to filter it or replace it with new solution, and Nitrate of Silver is an expensive salt, particularly in India, though only 4*s.* 6*d.* an ounce in England. Pyrogallic Acid is also a troublesomely delicate salt, and if not kept in the dark will spoil. Protosulphate of Iron, which produces admirable positives, is much cheaper and easier to keep.

11.—These are a few of the troubles which the amateur will encounter, and for which he must be prepared; that they are to be overcome by patience and perseverance, however, he need not doubt, and such is the fascination of the pursuit and so great the satisfaction derived (at all events to the artist himself) from even indifferent results, that few who have commenced, will feel disposed to withdraw from it, if they possess any *perseverance,* but without this, I would certainly recommend no one to waste his money on the necessary "*plant,*" or his time, which might be better employed, in dirtying his fingers, an invariable result of all Collodion working.

12.—Every day is now smoothing the path of Photographers. Collodion (uniodized) may be sent out from England or purchased in Calcutta; indeed, what is perhaps still better (but this I have not yet tried) the Gun Cotton and the Ether may be purchased separately and subsequently mixed. Iodizing solution may also be purchased ready made, separately.

13.—The simplest kind of bath, and the readiest to handle which I know, is a perpendicular glass one, in which, by the aid of a broad piece of Gutta Percha, turned up at the end to support the glass plate, the latter is at once immersed or withdrawn from the Nitrate of Silver solution. Glass baths are so liable to be broken, and so difficult to procure, that Gutta Percha and Porcelain must frequently be used.

14.—It is difficult to say what the cost of first establishing a Photographic apparatus would be. One sufficiently good to answer every purpose may be obtained for £10 or £12, while a fine and a large lens, if that be insisted on, will alone cost £40 or £50. This must, therefore, be left to the wishes and means of the individual. Fine or extensive landscape views cannot be taken without a large and expensive Lens.

15.—In the direct paper process several minutes are required to take a view, while the superior sensitiveness of Collodion is such that

from 5 to 20 seconds suffice for all ordinary purposes, while occasionally impressions may be obtained with momentary rapidity, that is in less even than one second. If a negative be taken a number of positives may be printed from it on to sensitive paper, and the glass washed and again used. If a positive be taken it may be mounted on black velvet and framed, when, if a good one, it will appear like an engraving of the most exquisite fineness.

16.—Much more might be said on this subject, but it would be useless to enter into the details of the different processes, which can also be learned from the standard books before mentioned, or from others equally good. Hunt's book will teach the learner every thing he wishes to know, and the Photographic Journal published monthly by Taylor and Francis, Red Lion Court, Fleet Street, price 6*d.*, will keep his knowledge up to the mark of the present day.

17.—In this beautiful Art, chemical knowledge cannot fail to be most useful to the practitioner, and if not acquired before, it is so involuntarily, after commencing to work at Photography. The great requisites are careful manipulation and a perseverance which will not be daunted by failures; with the aid of these, the art supplies not only an unfailing and entertaining amusement, but a power which may be turned to most useful account for scientific and other purposes, while, as I have said, the satisfaction derived from it is such as pleasurably to absorb all the leisure that can be spared for it.

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